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An electromagnetic compatibility analysis of the AN/URC-109 HF Wideband Communication System as installed on the LHD-1 Amphibious Assault Ship

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Monterey, California

THESIS

AN ELECTROMAGNETIC COMPATIBILITY ANALYSIS
OF THE AN/URC-109 HF WIDEBAND
COMMUNICATION SYSTEM AS INSTALLED ON THE
LHD-1 AMPHIBIOUS ASSAULT SHIP

by

George A. Seaver, Jr.

March 1988

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by

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A. THE HIGH FREQUENCY (HF) WIDEBAND COMMUNICATION SYSTEM

1. Background

In a worst case operational scenario for U.S. naval vessels, the assumption would have to be made that satellite communications would be impossible, and that essentially all external communications would have to be made with high frequency (HF) communication systems. Conventional communication systems have numerous disadvantages which might limit successful use in the above situation.

A wideband communication system was developed by the British Navy in response to the problems encountered with conventional systems in an active environment (combat conditions). The Royal Navy has used such a system quite successfully on smaller ships and will eventually implement it fleetwide [Ref. 1: p. 4].

The U.S. Navy will utilize the wideband architecture for the first time on the new LHD-1 class of amphibious assault ships. The designation of the system is AN/URC-109. The system will be required to handle twenty-two simultaneous circuits. This study will provide a detailed electromagnetic compatibility evaluation of the AN/URC-109 system under worst-case operating conditions.

2. System Overview

A conventional HF communication system architecture is shown in Figure 1. As can be seen, each transmitter has a separate power amplifier. The outputs of all of the power amplifiers feed into a manual patch panel (most common), or an automatic switching matrix (newer systems). The signal is then routed to the RF distribution system which consists of a four or eight channel multicoupler and the antennas.

The multichannel multicouplers enable several transmitters to use the same relatively broadband antennas. The multicouplers also provide isolation, impedance matching and filtering. Most ships are also equipped with single circuit 10 meter (35 ft) base-tuned whip antennas. These are tunable over the standard HF band (2-30 MHZ).

The development of multicouplers and tuners which provide isolation and filtering as well as impedance matching was driven by the efficiency with which the antenna systems coupled undesired signals as well as desired signals. The solution to that problem was seen to be operation with as narrow a bandwidth as possible at each operating frequency [Ref 1: pp.4-6].

The efficiency of the multicouplers and tuners with respect to isolation and filtering is determined by how far apart the operating frequencies are. Typically, a minimum 5% separation is required between transmitters or between transmitters and receivers.

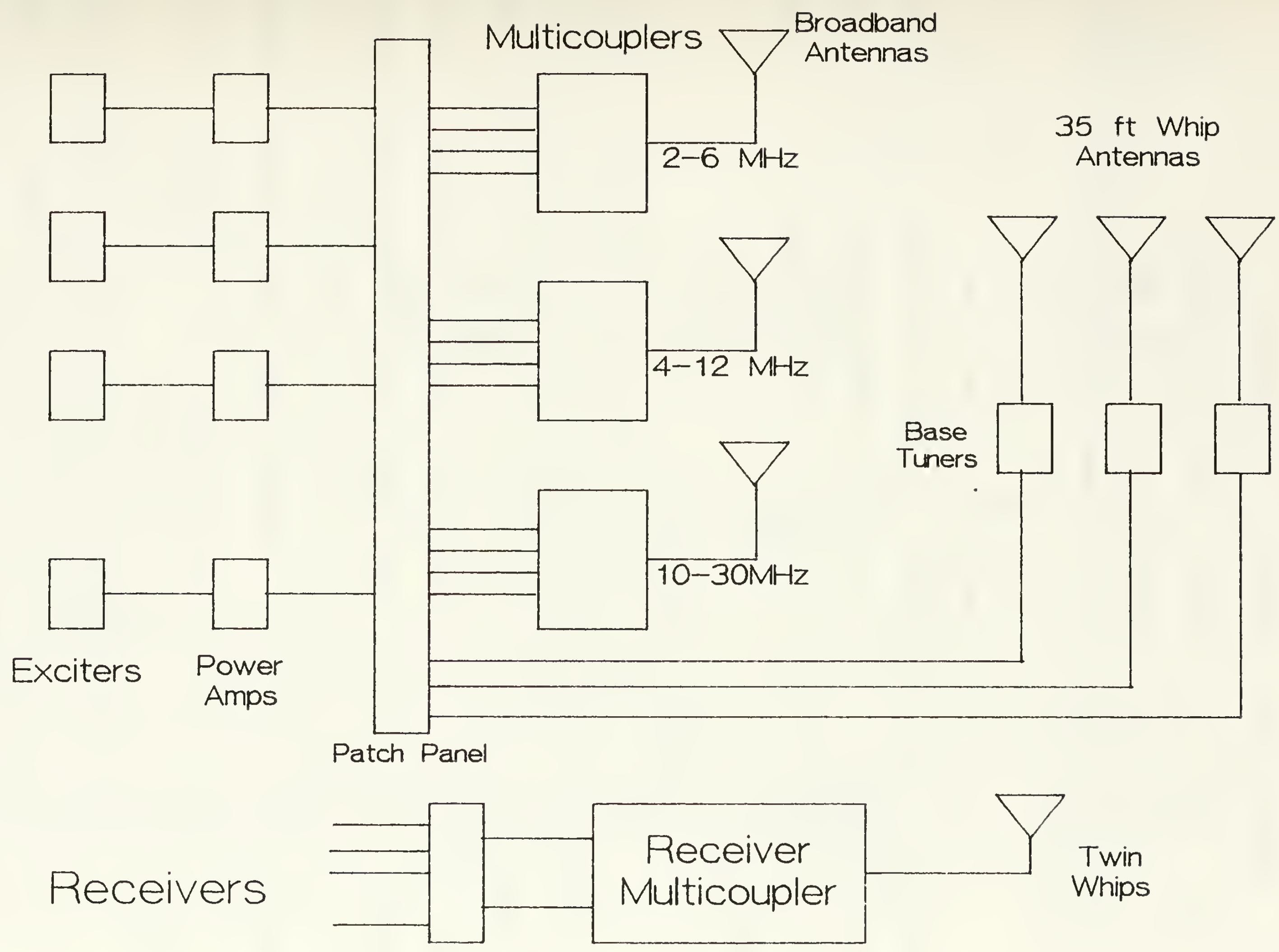

Figure 1. Conventional HF Architecture

Conventional narrowband HF systems suffer from the following disadvantages:

- The above listed frequency constraints.
- Time consuming frequency change procedures.
- The narrowband architecture is not able to utilize the wideband signal structures which are considered a key to circuit survivability if communications jamming is taking place [Ref 1: p. 6].

To overcome the above disadvantages, a wideband HF architecture was developed. Figure 2 provides a basic block diagram overview of a wideband communication system. The system is divided into a transmit subsystem and a receive subsystem.

a. Transmit Subsystem

The drive units are the equivalent of the exciters in the narrowband system. They provide buffering and up-conversion of the input signals. A key feature of this system is that the drive units have considerably better frequency flexibility than their narrowband counterparts. Typical response time of the unit to a frequency change from a remote control station (operator position) is one second. There are no restrictions on minimum frequency separation [Ref. 1: p. 6].

The signals from the various drive units are combined in the combiner and sent on to the transmitter power bank where they are amplified to transmission level. The

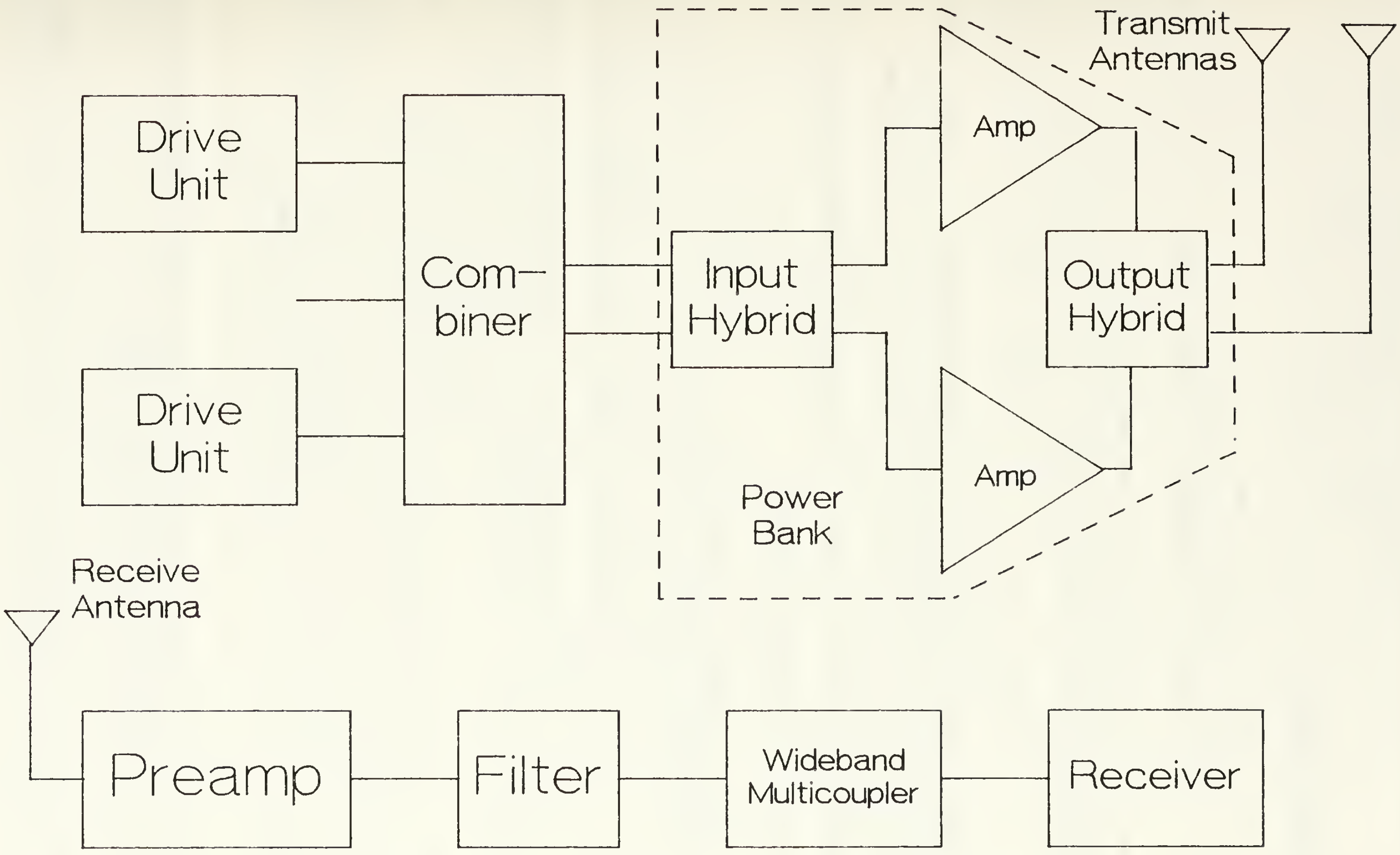

Figure 2. HF Wideband Architecture

power bank is connected to the two broadband HF transmit antennas, one for the 2-9 MHZ frequency range, the other for the 9-30 MHZ range.

b. Receive Subsystem

The basic wideband system uses a single electrically small active broadband antenna which covers the entire HF communications frequency band. The received signals are routed to wideband multicouplers where they are distributed to the appropriate receiver. Receivers may be tuned from the front panel as well as from remote operator positions. Like the transmitter drive units, frequency change response time is on the order of one second.

3. <u>Advantages/Disadvantages</u>

While the wideband communication system overcomes many of the disadvantages of the conventional narrowband system, it is highly susceptible to self-generated interference which could, if not properly controlled, reduce the performance level of the system considerably. From a system design viewpoint, self-generated interference can be controlled, or at least reduced to acceptable levels, by the judicious application of one or more of the following:

- Ensuring that the receiver antenna and multicoupler amplifiers have a wide dynamic range, in order to reduce receiver intermodulation distortion.
- Ensuring that transmitter internal distortion is kept to a minimum by using highly linear power amplifiers in the power bank.

- Proper positioning of receive and transmit antennas to provide adequate space isolation.

- Use of the electrically small active receiving antenna to further reduce coupling between transmit and receive systems.

- Ensuring that transmitted broadband noise is kept to a minimum.

There are several important advantages of the wideband system. Among them are:

- Frequency flexibility. The system can be tuned from any frequency to any other frequency in approximately one second, limited only by synthesizer settling time.

- No minimum frequency separation between transmitters.

- Only 2.5% separation required between transmit and receive frequencies.

- Avoids the use of mechanically tuned components.

- The system is a shared asset. Dedicated circuits and equipment are not required.

B. THE ELECTROMAGNETIC INTERFERENCE (EMI) PROBLEM

1. Interference Types

With the potential for self-generated interference discussed above, the electromagnetic compatibility of the wideband communication system is of primary interest. The installation of the system on the LHD-1 platform will entail much greater complexity, many more circuits and much greater power bank demand than installations on British ships to date.

In order to more fully understand the scope of the problem, a discussion of the types of interference which will have the greatest impact on system operation is required. The computer program (COSAM II (DECAL/PECAL)) used in this study evaluates the following types of interference [Ref. 2: p. 3]:

- Receiver Adjacent Signal (RAS): undesired power at the transmitter tuned frequency, in the presence of a desired signal.

- Transmitter Adjacent Signal (TAS): undesired transmitter spectrum (including broadband transmitter noise but not including narrowband spurious emissions) that lies inside the nominal passband of the receiver.

- Spurious Emissions (SE): narrowband spurious emissions of the undesired transmitter (not including broadband noise) that are close in frequency to the tuned frequency of the receiver. Transmitter harmonics are included.

- Spurious Response (SR): undesired power at the tuned frequency of the undesired transmitter when the frequency is close to one of the spurious response frequencies of the receiver. Image response is included.

- Receiver Intermodulation (RIM): undesired power resulting from the mixing of undesired transmitter signals in the receiver.

- Back Transmitter Intermodulation (TIM): undesired power resulting from the mixing of undesired transmitter signals in a narrowband transmitter.

- Forward Transmitter Intermodulation (FTIM): the mixing of exciter signals in the transmit system power bank. Does not include signals from narrowband transmitters.

An interference interaction is specified by naming the interference type and the coupling path under evaluation. For example, a typical interference interaction might be: RAS, transmitter #9, receiver #22.

2. EMC Problems of the AN/URC-109

A reference level which will be used in this discussion, called the Quasi-minimum Noise Level (QMN), requires some explanation. The QMN level has been established, as a function of frequency, for external noise levels aboard ship. The QMN levels were developed from experimental data obtained for all seasons of the year and for a variety of geographic locations.

Receive Subsystem EMC Problems: The self-generated interference in the receive subsystem of the wideband communication system can exceed the QMN by 3-11 dB, depending on frequency. A conventional HF communication system, on the other hand, generates 12 dB less noise than a wideband system [Ref. 1: p. 2].

Transmit Subsystem EMC Problems: In the transmit subsystem, the level of broadband noise generated can exceed the QMN depending on the antenna geometry. The primary EMC problem with the transmitting subsystem is, however, the intermodulation products developed in the wideband power bank. These intermodulation products could form an equivalent noise floor at levels much greater than the QMN, thus degrading system performance. In a study conducted by the Naval Research Laboratory [Ref. 1: p. 2], using four carrier frequencies each modulated with sixteen tones spaced over a 3 KHZ bandwidth, the thirteenth order intermodulation products

generated in the power bank essentially fill the HF band at a level exceeding the QMN by at least 42 dB.

C. SOLUTIONS TO THE EMI PROBLEM

Various design techniques for minimizing self-generated interference have been discussed previously. The remainder of this study will be an analysis of a system already designed for installation aboard the LHD-1. Once a system is designed and installed, EMC becomes chiefly the problem of the operator.

There are three basic techniques by which the operator can achieve optimum performance of the wideband system with respect to EMC.

1. Power Management

Power management is the reduction of transmitted power in order to reduce higher order intermodulation product power below receiver noise levels. Power management by itself, however, does not usually provide a solution to an interference problem, due to the following considerations [Ref. 2: p. 17]:

- Each circuit has a maximum peak envelope power (PEP) of 750 Watts.
- The PEP of individual circuits can be reduced only in discrete 3 dB steps (fifteen steps total).
- The PEP of all circuits combined is not permitted to exceed the average power rating of the power bank (6 KW).
- The average power rating of the power bank must be reduced according to the number of circuits simultaneously

transmitting that have a crest factor (PEP/Average Power) of less than three. This reduction is as great as 3 dB for six or more simultaneous circuits.

- The reduction of power reduces the range over which the circuit can be operated, an operational constraint which may be unacceptable.

2. Frequency Management

Frequency management is the assignment of operating frequencies from a set of frequencies which is intermodulation-free to a certain order. This means that no subset of frequencies in the IM-free set has the possibility of producing intermodulation products with any other frequency in the set. Table 1, obtained from Reference 2, contains various IM-free subsets of a set of 23 frequencies which is used in operational communications plans. As can be seen from the table, only seventeen of these frequencies may be used simultaneously if third order intermodulation products are to be prevented. If all 23 frequencies are used, third order intermodulation products will be present.

Frequency management is an effective method of preventing or reducing self-generated interference, provided that the operational scenario does not require selection of frequencies which will cause lower order intermodulation products. If that is the case, a combination of solution techniques must be used. For example, the higher order interference can be reduced by power management, and the lower order interference by frequency management.

TABLE 1

INTERMODULATION-FREE SETS OF FREQUENCIES

FREQ	LOWEST PERMISSIBLE ORDER																			
MHZ	4			6							8		10* and 12							
22.419	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x		
19.604	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
18.205	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x
16.167	x	x	x	x	x	x	x	x	x	x	x	x							x	
12.465	x	x		x	x	x				x		x	x					x		x
11.600	x	x	x	x			x	x			x			x	x			x	x	
9.397	x						x	x			x					x	x	x		
9.213		x	x	x	x	x			x			x		x	x				x	
8.027	x	x	x		x	x			x	x						x			x	
7.795	x	x	x							x										
6.228	x	x	x		x	x			x									x		x
5.228		x	x	x						x	x	x		x						
5.086	x	x	x				x			x										
4.925	x	x	x	x	x				x											
4.529	x	x	x				x	x	x											x
4.167	x	x	x		x	x	x	x	x											
3.566	x	x	x			x				x										
3.266												x	x							
3.263																				
2.634	x	x	x	x		x		x	x	x			x		x		x			x
2.514			x				x	x		x							x			
2.410					x		x	x								x				
2.065	x			x							x									
NUMBER OF FREQ IN THE LARGEST IM-FREE SUBSET	17			11							8		6							
SUBSET #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

* There are more than 100 subsets of IM-free frequencies which have a lowest permissible order of 10. Each frequency subset consists of six frequencies.

3. Time Management

The last of the general solution techniques to be presented is time management. If, after operational considerations, power management and frequency management have not reduced the predicted interference to an acceptable level, the number of simultaneously transmitting circuits may have to be reduced. This would require careful planning and coordination, however, in a scenario such as an amphibious assault which tasks the limits of the system.

Another related type of time management which may be more acceptable from an operational viewpoint is the reduction of the duty cycle of one or more circuits. While this method would not eliminate FTIM interference, it would reduce the probability of such interference causing unacceptable disturbances in the communication links. For example, a secure voice circuit transmitting on a frequency which would cause lower order intermodulation interference may have a duty cycle of 0.008, which means that it is very unlikely to cause unacceptable levels of interference with a circuit with a similarly low duty cycle.

D. COSAM II (DECAL/PECAL) - THE EVALUATION TOOL

The Naval Ocean System Center (NOSC) is currently working, in conjunction with the University of Kansas, on an integration of numerous computer codes that have been developed over the years for the engineering analysis of shipboard

exterior communication systems. These codes can be grouped into two general categories: one for antenna modelling and one for communication system analysis. The integrated code, called Communication Engineering Design System (COEDS), will provide a user friendly interface of the various codes, and will embody a structured design procedure. COEDS is expected to be completed in mid to late 1989.

One of the key subprograms of COEDS is the system analysis model called COSAM II (DECAL/PECAL). (Translation: COsite Analysis Model, Version II (DEsign Communications Algorithm/ Performance Evaluation Communications Algorithm)). This program is a combination of the major features of the original COSAM, DECAL, and PECAL programs. Although DECAL and PECAL were originally limited to the analysis of narrowband systems, COSAM II (DECAL/PECAL) has provisions for the evaluation of wideband systems as well. It is thus ideally suited for evaluation of the URC-109 installation on the LHD-1 [Ref. 3: p. 48.6.1].

NOSC has conducted a preliminary study of the URC-109 system as it will be installed on the LHD-1 using COSAM II (DECAL/PECAL) (WIDEBAND for short), which consisted of evaluating the interference interactions of five of the twenty-two communications circuits, representing the five types of circuits involved. This study will be a more complete evaluation of the system as it will be installed on the LHD-1, using an up-to-date data base and a current operational

scenario. In the process, the WIDEBAND program will be evaluated for user-friendliness and possible bugs that will require correction before WIDEBAND is integrated into COEDS.

II. DESCRIPTION OF THE AN/URC-109 SYSTEM

A. BLOCK DIAGRAM DESCRIPTION

1. Transmit Subsystem

Figure 3 is a block diagram of the AN/URC-109 transmit subsystem [Ref. 4: p. A-3]. There are six drive outfits with various combinations of drive units for upper and lower sideband transmissions. There are twenty-two drive units, and thus twenty-two possible simultaneous transmit circuits. The outputs of the drive units are combined in the drive combiner which then sends the combined signal to the power bank. There are six 1 kW power banks connected in parallel, providing a total average power output capacity for the system of 6 kW.

The power bank consists of an input hybrid, a push-pull power amplifier and an output hybrid. This configuration is shown in Figure 4 [Ref. 1: p. 8]. The hybrids are ferrite-core transformers which isolate the signals in the 2-9 MHz band ports from those in the 9-30 MHz ports. They also isolate the power amplifiers from each other. The output of the power banks is routed to the antennas through RF combiners and impedance matching networks.

The transmit antennas were designed by NOSC specifically for the LHD-1 installation, based on studies conducted using a 1/48th scale brass model. The 2-9 MHz antenna consists of a twin fan configuration which is draped

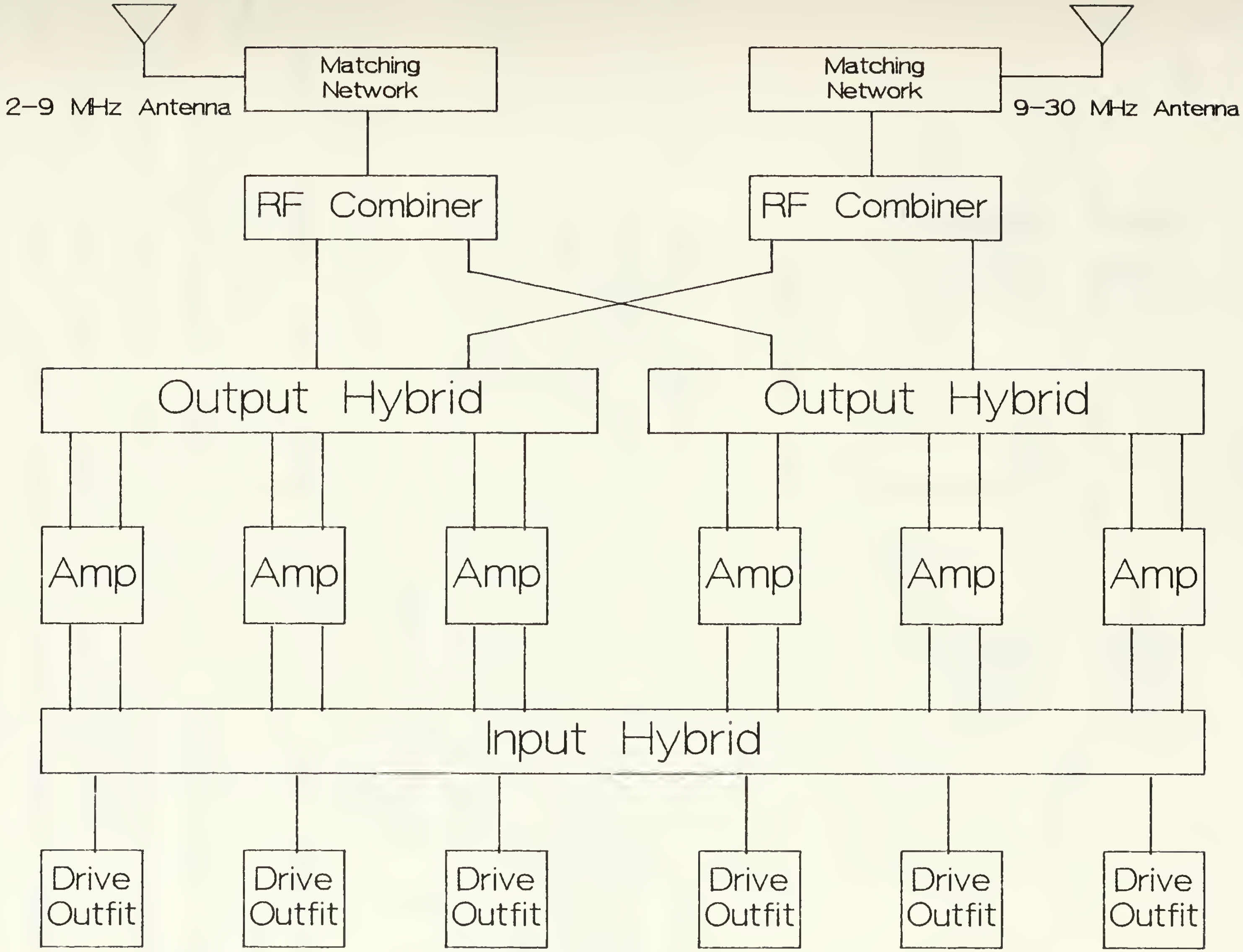

Figure 3. AN/URC-109 Transmit Subsystem

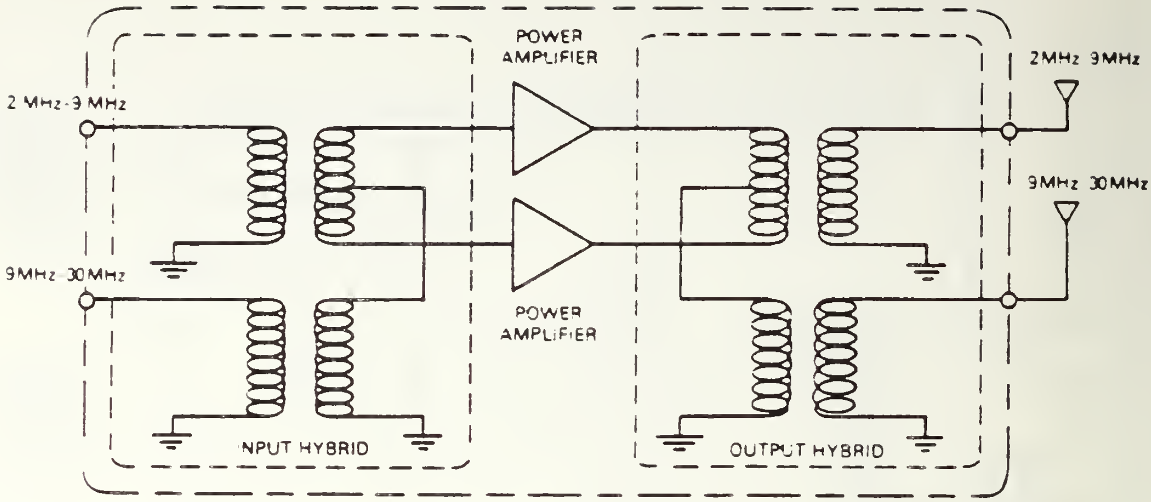

Figure 4. Power Bank Configuration

forward from the aft mast yardarm. This provides the necessary length without potential interference with the signal halyards. The 9-30 MHz antenna consists of an 18-foot twin whip arrangement located on the 06 level, frame 80.5, 16 feet from the island centerline [Ref. 4: p. 3-1].

2. <u>Receive Subsystem</u>

Figure 5 is a block diagram of the AN/URC-109 receive subsystem [Ref. 4: p. A-5]. There are a total of eight receiver outfits consisting of various combinations of upper and lower sideband receivers. Each receiver outfit also contains a multicoupler. The received signals are preamplified at the antenna (discussed below), and routed through the antenna select switch to the appropriate multicoupler. The system can operate over the VLF, LF, MF and HF communications

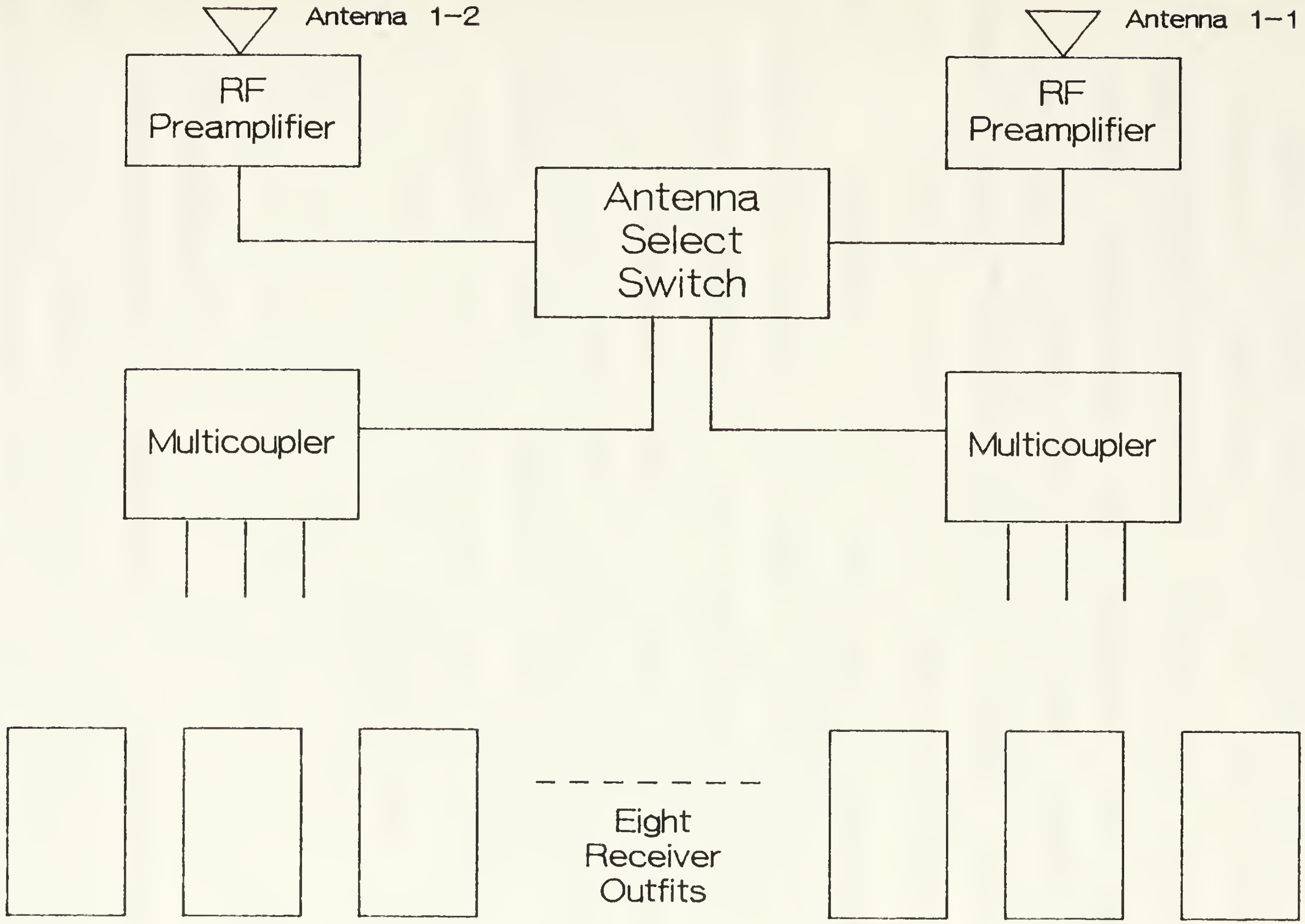

Figure 5. AN/URC-109 Receive Subsystem

bands, but only HF operation will be considered in this study.

Each of the receiving antennas contains an integral RF preamplifier, which is the primary determinant of receive subsystem sensitivity. The receive antennas consist of two AVK active antennas located at about frame 124 on the port and starboard sides of the flight deck catwalk [Ref. 4: p. 3-3]. The antennas are electrically small at frequencies of about 20 MHz or less.

B. NOISE CONSIDERATIONS

As discussed in Chapter 1, there are two phenomena that can seriously degrade the performance of the wideband communication system. These phenomena are noise and intermodulation distortion. While this report deals primarily with intermodulation problems, a brief discussion of the noise characteristics of the system is in order.

1. Types of Noise

There are two general types of noise, continuous and impulse. Continuous noise is noise that is relatively uniform and continuously present. The noise power of continuous noise is proportional to the bandwidth of the receiver. Examples are noise jammers, some spurious emissions from communications receivers, galactic noise, etc. Impulsive noise, on the other hand, is of high intensity and short duration. Examples are automotive ignitions, power line discharges, the

sparking of motor brushes and gas tube discharges. Many noises are a combination of the two types of noise, with bandwidth characteristics which lie between the two types [Ref. 5: p. 17].

2. Ambient Noise

Ambient noise is due primarily to radiated interference. This radiated interference may be from either functional sources or non-functional sources. Noise from functional sources arises from the normal functioning of a component or subsystem, and the noise usually interferes with other parts of the same system. Examples are local oscillators and transmitters. Non-functional sources produce noise energy which is not useful. It may be either natural or a by-product of the generation of useful radiation. Natural noise includes atmospheric noise which is caused by lightning strikes, and cosmic noise which comes from celestial bodies. Below about 10 MHz, man-made noise is predominant. In the 20-300 MHz range, cosmic noise is predominant [Ref. 5: pp. 33-35].

3. System Noise

System noise is a combination of radiated noise and conducted noise. Conducted noise may also be functional or non-functional, but, unlike radiated noise, it is transmitted through a conducting medium such as wiring or metal equipment casings. The system noise figure is a figure of merit which

specifies how much noise the system adds to an incoming signal. In basic terms, noise figure is given by:

$$N.F. = 10 \log (1 + Teq/290) \quad (dB) \qquad 2.1$$

The equivalent temperature, Teq, is the sum of the background temperature and the equivalent temperatures of each receiver stage, referred back to the input of the receiver. The background temperature is an integration of a relatively uniform sky temperature with specific localized galactic sources such as the sun, moon and stars, which appear in the field of view of the antenna [Ref. 6:pp. 100-110].

4. AN/URC-109 Noise

System noise in the URC-109 consists of broadband transmitter noise and receiver noise. The primary source of transmitted broadband noise is the drive units of the 1 kW power banks. This noise is approximately 130 to 135 dB below 1 kW, assuming a bandwidth of 3 kHz and a frequency separation of 2.5%. This level exceeds the QMN by approximately 12 dB [Ref. 1: p. 16-21]. Receiver noise factor varies from approximately 55 dB at the low end of the band to approximately 31 dB at the high end of the band. This noise factor results from the noise power generated within the numerous active receiver circuits, such as RF amplifiers, IF amplifiers, etc. [Ref 1: p. 30].

C. OPERATING SCENARIO

1. Typical Circuit Requirements

The LHD-1 Amphibious Assault Ship was designed to replace the aging LHA class of assault ships. With its large flight deck and extensive communications suite, it will typically be the flagship of a multi-ship amphibious task force. There are five types of external communication circuits required for the LHD-1: secure voice, unsecure voice, multi-channel RATT, single-channel RATT, and LINK-11 A total of twenty-three HF circuits are required for a typical amphibious landing operation. A detailed evaluation has been made to determine the scenario of HF transmissions which would be likely to occur during an ambhibious exercise. This information was used to compute the duty cycle of each circuit as well as the maximum number of simultaneous transmissions to be expected. Table 2 provides a list of the required circuits, with circuit type and duty cycle indicated The assumption was made that satellite communications would be unavailable. Of note is the fact that there is only one LINK-11 circuit and one multi-channel RATT circuit. [Ref. 2: pp. 11-15]

2. Maximum Simultaneous Circuits

According to the evaluation discussed above, a maximum of five of the twenty-three HF circuits to be used during the landing scenario would be transmitting during the same minute. Since many of the transmissions would be extremely

TABLE 2

LHD-1 HF CIRCUITS

HF CIRCUIT	CIRCUIT TYPE	DUTY CYCLE
Naval Gunfire Control	Secure Voice	0.025
Landing Force Fire Support Coord	Secure Voice	0.008
Conference Command Alfa	Secure Voice	0.008
Beach Boat Control	Unsecure Voice*	0.058
Landing Force Command	Secure Voice	0.033
Landing Force Tactical	Secure Voice	0.100
Landing Force Intelligence	Secure Voice	0.025
LF Artillery Command/Fire Direction	Secure Voice	0.025
TF/TG Special Intelligence	Secure Voice	0.042
Data Systems Administration	Secure Voice	0.042
AAW Intersector C & R	Secure Voice	0.033
Tactical Air Request	Secure Voice	0.050
Landing Force Medical Regulations	Unsecure Voice*	0.025
TF/TG Operations/Administrative	Single Chan. RATT	1.0**
LINK 11	LINK 11	1.000
Helicopter Request	Secure Voice	0.017
Tactical Air Command	Secure Voice	0.008
FAAD Weapon Control	Secure Voice	0.050
Landing Force HST Control	Secure Voice	0.033
TF/TG Command	Secure Voice	0.067
SI Coordination	Single Chan. RATT	0.5**
HICOM	Secure Voice	0.025
Primary Ship-to-Shore	Multi-channel RATT	1.000

NOTES:

* Usually secure voice is used. Unsecure voice is assumed in order to include all five circuit types in the analysis.

** The value of duty cycle has been increased because some circuits will probably carry additional traffic unrelated to scenario events.

brief, the actual number of simultaneous transmissions would probably be even less. However, with the potential for many more circuits transmitting simultaneously, and given the fact that a worst-case condition will eventually occur, it was

decided to evaluate the system's performance with each receiver being irradiated by twenty-two transmitters. The COSAM II (DECAL/PECAL) program was used to conduct the evaluation. A detailed analysis of the results will be presented.

III. COSAM II (DECAL/PECAL) WIDEBAND ANALYSIS PROGRAM

A. BACKGROUND

1. History

As discussed in Chapter 1, COSAM II (DECAL/PECAL) was developed to incorporate the earlier cosite analysis model (COSAM) with the design communications algorithm (DECAL) and the performance communications algorithm (PECAL). The program used in this study was a further development of this consolidated program called the COSAM II (DECAL/PECAL) WIDEBAND AND NARROWBAND RF ARCHITECTURE ANALYSIS PROGRAM. The original version of COSAM II (DECAL/PECAL) included provisions for the analysis of frequency hoppers, but not for the analysis of wideband architecture. WIDEBAND, on the other hand, can be used with wideband architecture, but not with frequency hoppers. WIDEBAND can accommodate up to 40 communications receivers, 40 communications or radar transmitters, 80 couplers, 40 decouplers and 80 antennas [Ref. 7: pp. 1-9,1-10].

2. Purpose

The purpose of WIDEBAND is to provide the design engineer with a tool to evaluate the overall performance of communication systems which are cosite configured and which have power levels which are large enough to require consideration of nonlinear effects [Ref. 7: p. 1-1]. WIDEBAND

accomplishes the analysis of the given system configuration by performing power calculations based on the input equipment parameters, desired power to undesired power ratios required, antenna location, etc. A detailed discussion of these power calculations will be provided later in this chapter.

3. The Concept of "PINO"

The key calculation performed by WIDEBAND for any given interference interaction is the equivalent input on-tune power (PINO). This variable is of crucial importance and will be described in some detail. It is defined as the amount of power at the receiver input and at the receiver tuned frequency that would result in the same detrimental effect at the receiver output as that actually produced by the off-tuned undesired power. For example, if an off-tuned, undesired signal has a power level at the receiver input of -90 dBm and the receiver provides 30 dB of rejection of the off-tuned signal, the PINO would be -120 dBm.

Since uncertainties exist in several of the variables which determine PINO, WIDEBAND treats PINO as a distribution of values. It is assumed to be a normal distribution with a mean value and a standard deviation. The desired power, ambient noise power, and receiver noise power are also assumed to be normally distributed variables [Ref. 7: p. 1-5]. Since PINO and the other specified power levels are distributions rather than exact values, the output of

WIDEBAND cannot be a strict "yes" or "no" answer, but rather it is a probability of satisfactory or unsatisfactory performance. The design engineer must decide what performance scores are acceptable.

4. Modes of Operation

WIDEBAND has two primary modes of operation: the Necessary Desired Power (NDP) Mode and the System Performance Score (SPS) Mode. These modes are selected by the user in the run file which executes the program (to be discussed later). The program automatically selects the wideband or narrowband mode based on whether the user has specified wideband equipment in the run file. There are also three input modes which determine the algorithm WIDEBAND uses to calculate antenna to antenna losses. These are: the coupling loss input mode, the coupling loss calculation mode, and the electric field input mode. These input modes will also be discussed in the following section.

a. Some Key Definitions

In order to provide a meaningful discussion of WIDEBAND program operation, some key terms must be defined. These are [Ref. 7: pp. 1-6,1-7]:

- System Performance Score (SPS): the probability that the receiver will perform satisfactorily in the presence of undesired noise and signal power.

- Upper Performance Score (UPS): the probability that the receiver will perform satisfactorily in the presence of noise but in the absence of undesired transmitter signal power. This is an upper limit for SPS.

- Individual Performance Score (IPS): the probability of satisfactory performance in the presence of a given interaction, but in the absence of noise and of any other interactions.
- Excess Interference Level (EIL): the additional path loss, in dB, which would reduce the PINO such that the IPS equals a given target value.

b. The Necessary Desired Power (NDP) Mode

This mode produces, as its major output, the mean desired power required in order to achieve a system performance score which has been specified by the user. If, for example, a SPS of 0.90 is desired, WIDEBAND will calculate the mean necessary desired power required to achieve that score, taking into account the standard deviation of the desired power and the level of undesired power present at the receiver input.

WIDEBAND will perform the same calculations to determine the necessary desired power required for a specified UPS value. Based on the calculated value of the necessary desired power required for the UPS target, WIDEBAND also provides the IPS and EIL for each significant interference interaction.

c. The System Performance Score (SPS) Mode

The major output of the program in SPS mode is the system performance score. If this score is high, it is a good indication that the system will perform satisfactorily in its given environment. This mode requires that the user enter a receiver performance threshold which may be the

articulation index, the bit-error rate, or the desired to undesired power ratio at the receiver output. The program converts the threshold into a desired to undesired power ratio at the input to the receiver. The calculated D/U value is then compared to the threshold value to determine receiver performance. Receiver performance is satisfactory when the desired power exceeds the ambient noise power, receiver noise power, and PINO (individually) by at least the threshold level [Ref. 7: p. 1-6].

d. Input Modes

The input mode determines how the program calculates antenna-to-antenna losses. In the coupling loss input mode, the user must input the antenna-to-antenna coupling loss curve for each transmit/receive antenna pair. The driving point impedance curve of the wideband receive antenna must also be input by the user.

In the coupling loss calculation mode, antenna-to-antenna coupling losses are calculated by the program using a standard algorithm.

In the electric field mode, the user provides the program with electric field strength curves at the receive antenna for each transmit/receive antenna pair. The user must also enter the driving point impedance of the wideband receive antenna [Ref. 7: p. 1-9].

B. INPUT FILES

WIDEBAND uses two types of files in its execution: the data base files and the run file. They will be described in detail below, and examples will be provided of each file type.

1. Data base Files

WIDEBAND requires access to four data files which comprise the data base for the installation being evaluated. These are: the equipment parameter file (EPF), the coupler/decoupler file (CDF), the degradation curve parameter file (DCPF), and the generalized data file (GDF). These files, once established for a particular equipment installation, remain unchanged during program execution. They are briefly described in the following sections.

a. The Equipment Parameter File (EPF)

The EPF is WIDEBAND's source for all required receiver and transmitter data. It contains receiver records and transmitter records. There must be one receiver record for each type of receiver being considered by WIDEBAND. Likewise, there must be one transmitter record for each transmitter type.

Receiver records contain the following data:

- Tuning range, type of modulation, receiver sensitivity and bandwidth.

- Data concerning intermediate, local oscillator and crystal frequencies.

- Spurious response (SR) attenuation levels.

- Receiver adjacent signal (RAS) model parameters.

- Data which will enable calculation of receiver intermodulation (RIM) losses in the front end of the receiver.

Transmitter records contain the following data:

- Tuning range, type of modulation and transmitter power.

- Data concerning intermediate, local oscillator and crystal frequencies.

- Spurious emission (SE) attenuation levels.

- Data which will enable calculation of transmitter intermodulation (TIM) losses in the output circuits of the transmitter.

- Emission spectral density curve parameters.

b. The Coupler/Decoupler File (CDF)

This file contains the data records for the linear couplers and decouplers. The linear coupler records contain the tuning range of the coupler and a set of data points on the coupler rejection curve. The decoupler records contain basically the same information for the decouplers; however, there are three rejection curves for the decouplers corresponding to the three possible paths through the decoupler.

c. The Degradation Curve Parameter File (DCPF)

The DCPF, as the name implies, contains degradation curve records for two types of analyses. If the undesired power being calculated is noise, the DCPF provides data points for the curve of articulation index (or bit-error-rate) versus receiver signal to noise ratio. For all

other cases, AI (or BER) versus signal to interference level curves are provided [Ref. 7: p. 2-5].

d. The Generalized Data File (GDF)

The GDF contains nonlinear coupler records, wideband receive antenna/preamplifier records, and wideband power bank records.

The nonlinear coupler records contain data concerning coupler gain, coupler cross modulation, and intermodulation/harmonic model parameters. The wideband receive antenna/preamplifier records contain information required for the calculation of path loss or gain associated with the wideband antenna. The power bank record contains the rated power of the power bank and transmitter adjacent signal and forward transmitter intermodulation parameters. All other transmitter parameters are contained in the transmitter records of the EPF [Ref. 7:pp. 2-10,2-11].

2. The Run File

WIDEBAND is executed by means of a run file which may consist of either a deck of input cards or a command file containing the same information. In the run file, the user tells WIDEBAND all of the information required for the program to evaluate the particular equipment configuration being evaluated. There are twenty-two input card types in the run deck. Not all cards are required for every run, however. A brief description of each relevant card type follows. A

sample run file is illustrated in Figure 6.

- Identification (ID) Card: provides an identifying word or phrase for the program run.

- Equipment (EQ) Card: tells the program the number of transmitters, receivers, couplers, decouplers, and antennas in the configuration.

- Option (OP) Card: selects which types of interactions are to be calculated and which are to be omitted. It also selects the method of calculating antenna-to-antenna losses, what type of EIL output is desired, and the method of calculating wideband receive antenna pre-amplifier losses.

- First Parameter (P1) Card: selects mode of operation (NDP or SPS); selects target values for UPS, SPS, and IPS; provides the standard deviation of the ambient noise distribution; provides the minimum distance between antennas; and provides the maximum intermodulation order to be considered.

- Second Parameter (P2) Card: provides the maximum number of transmission states to be considered, a random number generation seed, the selected power of the transmitter power bank, and some geometry information for installations on aircraft.

- Transmitter (TX) Card: specifies the transmitter number, nomenclature, connectivity, frequency, modulation type, power, crest factor (ratio of peak envelope power to average power) and duty cycle, and whether the transmitter is pulsed or not.

- Receiver (RX) Card: specifies the receiver number, nomenclature, connectivity, frequency, modulation type, mean desired power, type of performance threshold to be used (AI, BER, or D/U), and threshold value.

- Linear Coupler (CU) Card: specifies coupler number, nomenclature, and connectivity.

- Nonlinear Coupler (NL) Card: specifies coupler number, nomenclature, and connectivity.

- Decoupler (DC) Card: specifies decoupler number, nomenclature, and connectivity.

- Surface Antenna (SA) Card: specifies antenna number, nomenclature, location (x, y, and z coordinates), polarization, and gain.

- Wideband Nomenclature (WB) Card: specifies the receiver and transmitter nomenclatures that the program will recognize as wideband equipments.

```
ID  'SAMPLE RUN -- WIDEBAND AND NARROWBAND'
EQ  4 4 0 1 0 5
OP  1 1 1 1 1 1 1 1 1 1 0 2 0 2 1
P1  6. 0 0. 0. .95 25 1 .1
P2  0. 0. 2 20 10
WB  AN/URC-109
TX  1 AN/URC-109 A 1 0 12.23 LINK11 58. 0 7. .4
TX  2 AN/URC-109 A 1 0 13.01 LINK11 58. 0 7. .3
TX  3 AN/URC-109 A 1 0 14.49 LINK11 58. 0 7. .2
TX  4 AN/URC-102-C A 4 0 16.6 A3A 60. 0 0. .10
RX  1 AN/URC-109 N 1 0 13.63 A3A -102. 6. D/U 10. 0
RX  2 AN/URC-109 N 1 0 26.72 A3A -102. 6. D/U 10. 0
RX  3 AN/URC-109 N 1 0 13.09 A3A -102. 6. D/U 10. 0
RX  4 AN/URC-102-B A 5 0 9.63 A3A -102.0 6.0 D/U 10. 0
NL  1 AN/URC-109 A 3 0
SA  1 A2-9 O. O. O. V -1.5 3.
SA  2 A9-30 0. 0.2 0. V -1.5 3.
SA  3 ANT 0. 100. 0. V -3.5 3.
SA  4 ANT 10. 100. 0. V -1.5 3.
SA  5 ANT 100. 0. 0. V -1.5 3.
```

Figure 6. Sample WIDEBAND Run File

C. PROGRAM OPERATION

1. Calculation of Undesired Power Levels

As discussed earlier, WIDEBAND uses the values of PINO that it calculates to evaluate the interference levels of each possible interference interaction. In this section, the equations used in these calculations for the most significant interaction models will be presented [Ref. 7: pp.2-16 - 2-43].

a. Receiver Adjacent Signal (RAS)

The mean PINO (in dBm) for the RAS interaction, taking into account nonlinear effects, is:

$$PINO = P_T - L_P(f_T) - \beta'(\delta f) + (1-M)(P_D - R_S - 5) \quad 3.1$$

where

P_T = mean output power of undesired transmitter (dBm)

$L_P(f_T)$ = mean path losses at frequency f_T (dB)

f_T = tuned frequency of undesired transmitter (MHz)

$\beta'(\delta f)$ = mean receiver rejection of the undesired power (dB)

δf = $f_T - f_R$ (MHz)

f_R = tuned frequency of the receiver (MHz)

M = slope of undesired power vs. desired power curve for a constant D/U ratio at receiver input (dBm)

P_D = mean desired power at the receiver input (dBm)

R_S = mean receiver sensitivity (dB)

The standard deviation of the RAS PINO distribution is:

$$\sigma(PINO) = \{\sigma^2(P_T) + \sigma^2(L_P) + \sigma^2(\beta') + (1-M)^2[\sigma^2(P_D) + \sigma^2(R_S)]\}^{1/2} \quad 3.2$$

b. Transmitter Adjacent Signal (TAS)

The mean PINO for the TAS interaction is:

$$PINO = S(\delta f) + 10 \log(B_R) - L_P(f_R) \quad (dBm) \quad 3.3$$

where

$S(\delta f)$ = mean undesired spectral power density (dBm/Hz)

$\delta f = f_R - f_T$ (MHz)

f_R = receiver tuned frequency (MHz)

f_T = transmitter tuned frequency (MHz)

B_R = receiver bandwidth (MHz)

$L_P(f_R)$ = mean path loss at frequency f_R (dB)

The standard deviation of the TAS PINO is:

$$\sigma(PINO) = [\sigma^2(S) + \sigma^2(B_R) + \sigma^2(L_P)]^{1/2} \qquad 3.4$$

c. Spurious Emissions (SE)

WIDEBAND calculates the PINO distribution for each spurious emission of a given transmitter-receiver pair. If the SE crest factor is less than or equal to 3 dB, the mean PINO is:

$$PINO = P_T - \beta_{SE} - L_P(f_{SE}) - \beta_{RT}(\delta f_{SE}) \quad (dBm) \qquad 3.5$$

where

P_T = mean output power of undesired transmitter (dBm)

β_{SE} = mean difference between power densities at the transmitter and SE frequencies (dB)

$L_P(f_{SE})$ = mean path loss at frequency f_{SE} (dB)

f_{SE} = SE frequency (MHz)

$\beta_{RT}(\delta f_{SE})$ = receiver-transmitter rejection (dB)

$\delta f_{SE} = f_{SE} - f_R$ (MHz)

f_R = receiver tuned frequency (MHz)

If the SE crest factor is greater than 3 dB, the mean PINO is given by:

$$PINO = P_T - \beta_{SE} - L_P(f_{SE}) - \beta_{RT}(\delta f_{SE}) + \\ + (1-n)CF + 10 \log (n!) \quad 3.6$$

where

n = harmonic order integer

CF = crest factor of transmitter signal (dB)

The standard deviation of the SE PINO is:

$$\sigma(PINO) = [\sigma^2(P_T) + \sigma^2(\beta_{SE}) + \sigma^2(L_P) + \sigma^2(\beta_{RT})]^{1/2} \quad 3.7$$

d. Forward Transmitter Intermodulation (FTIM)

The mean PINO for the FTIM model is:

$$PINO = P_{FTIM} - L_P(f_{FTIM}) - \beta_{RT}(\delta f) \quad (dBm) \quad 3.8$$

where

$L_P(f_{FTIM})$ = mean path loss at frequency f_{FTIM} (dB)

$\beta_{RT}(\delta f)$ = mean receiver rejection (dB)

$\delta f = f_{FTIM} - f_R$ (MHz)

f_R = receiver tuned frequency (MHz)

The standard deviation of the FTIM PINO is:

$$\sigma(PINO) = [\sum_{i=1}^{N} n_i^2 \sigma^2(P_i) + \sigma^2(K_{q'}) + \sigma^2(L_P) + \sigma^2(\beta_{RT})]^{1/2} \quad 3.9$$

2. Noise Calculations

WIDEBAND performs calculations for two types of noise: receiver noise and ambient noise. The mean receiver noise (in dBm) referred to the receiver input is:

$$U_{RN} = R_S - 10 + T \qquad 3.10$$

where

R_S = mean receiver sensitivity (dBm)

T = input/output transfer characteristic (dB)

The standard deviation of receiver noise is the same as the standard deviation of receiver sensitivity.

The mean ambient noise (in dBm) at the receiver input is:

$$U_{AN} = F_A(f_R) - 114 + 10 \log (B_R) - L_P(f_R) \qquad 3.11$$

where

B_R = receiver bandwidth (MHz)

$L_P(f_R)$ = antenna to receiver path loss (dB)

$F_A(f_R)$ = Ambient noise at receiver frequency, f_R (dB)

The standard deviation of the ambient noise is a run file parameter.

3. Path Losses

There are two general types of path losses considered by WIDEBAND: coupler/decoupler losses and antenna-to-antenna

losses. Linear coupler losses may either be calculated by WIDEBAND by use of a complex equation, or they may be interpolated from the appropriate CDF curve. Decoupler losses are calculated by interpolating the appropriate CDF curve.

Antenna-to-antenna losses are those experienced by a signal in the transit from transmitter to receiver. They are the result of propagation losses and antenna characteristics. As discussed earlier, there are three methods by which WIDEBAND obtains antenna-to-antenna losses:

- Input by user.
- Calculated by the program based on propagation models.
- Calculated by the program based on electric field strengths which are input by the user.

For the second case above, the calculation is based on the following equation:

$$L = MAX\ [-G_T - G_R + MAX\ (L_{FS},\ L_{GW}) + C,\ 8] + L_{AMP} \qquad 3.12$$

where

L = mean antenna-to-antenna coupling loss (dB)

G_T = mean gain of transmit antenna (dBi)

G_R = mean gain of receive antenna (dBi)

L_{FS} = free-space loss (dB)

L_{GW} = ground-wave loss (dB)

C = correction to free-space or ground-wave loss (dB)

L_{AMP} = wideband receive antenna preamplifier loss (dB)

For the case of calculations based on field strength, the following equation is used:

$$L = -20 \log E - 20 \log \left[\frac{50 + Z_{AMP}}{Z_{ANT} + Z_{AMP}}\right] - CR8 + CR1 - 13.0 \qquad 3.13$$

where

L = mean antenna-to-antenna coupling loss (dB)

E = magnitude of electric field strength at wideband receive antenna due to a 1 mW source applied to transmit antenna (V/m)

Z_{AMP} = impedance of the wideband preamplifier (ohms)

Z_{ANT} = driving point impedance of the wideband antenna subassembly (ohms)

C_{R1}, C_{R8} = first and eighth constants in GDF wideband receive antenna record

4. <u>Calculation of Desired/Undesired Power Ratio</u>

Probably the single most important calculation made by WIDEBAND is the desired/undesired power ratio (D/U). The user must input the performance threshold value, related to the receiver output. WIDEBAND then converts this threshold value into a D/U value referred to the receiver input. The undesired power levels calculated by the algorithms discussed in the previous section are then used to determine whether the receiver is performing satisfactorily.

If the threshold value input by the user is the output D/U ratio, the program calculates input D/U as follows:

$$(D/U)_{in} = (D/U)_{out} - T \qquad 3.14$$

where

$(D/U)_{in}$ = D/U threshold at receiver input (dB)

$(D/U)_{out}$ = D/U threshold at receiver output (dB)

T = tabulated input/ouput transfer characteristic (dB)

If the input threshold is AI or BER, the program uses a degradation curve from the DCPF to calculate the input D/U. The DCPF contains two curves for each undesired signal/receiver modulation type combination: one for a high signal-to-noise ratio and one for a low signal-to-noise ratio. The program uses the high signal-to-noise ratio curve in order that the undesired power level can be interpreted as the power output of an undesired transmitter without noise [Ref. 7: p. 2-80].

5. Calculation of Individual Performance Score (IPS)

The IPS provides the probability that a receiver will perform satisfactorily for a given interaction in the presence of that interaction, but in the absence of noise or any other interactions. This probability can be expressed as [Ref. 7: p. 2-83]:

$$IPS = Prob\ [D - U_i > T_i] \qquad 3.15$$

where

D = desired power at the receiver input (dBm)

U_i = PINO at the receiver input for the i-th interaction (dBm)

T_i = D/U threshold at the receiver input for the i-th interaction (dBm)

6. Calculation of Individual Error Probability (IEP)

The individual error probability (IEP) is defined as the probability that a receiver will perform unsatisfactorily in the presence of the given interaction, but in the absence of noise or any other interactions. Transmitter duty cycles are taken into account. The duty cycle of an interaction is defined as the product of the duty cycles of the transmitters involved in that interaction. The IEP is calculated as follows:

$$IEP = \Gamma(1 - IPS) \qquad 3.16$$

where

Γ = duty cycle of the interaction

IPS = individual performance score of the interaction

7. Calculation of Excess Interference Level (EIL)

The actual calculations involved in obtaining the EIL are beyond the scope of this study; however, the basic process involved in the calculation will be presented. WIDEBAND first must compute the mean PINO value which will provide an IPS which is equal to the target value input by

the user. The next step is to relate additional path loss to the associated reduction in the mean PINO. The additional path loss may be distributed in any way desired among the paths which make up the given interaction. Although the EIL is useful in determining the severity of interference for a particular interaction, the true indication of how well a system is designed is the system performance score (SPS) [Ref. 7: p. 2-88].

8. Calculation of Upper Performance Score (UPS)

As stated earlier, the UPS is the probability that a receiver will perform satisfactorily in the presence of noise, but in the absence of any undesired transmitter signals. UPS is calculated as follows:

$$UPS = \text{Prob}\ [D - U_1 > T_1 \text{ and } D - U_2 > T_2] \qquad 3.17$$

where

D = desired power at receiver input (dBm)

U_1 = ambient noise at receiver input (dBm)

T_1 = D/U threshold for ambient noise (dB)

U_2 = receiver noise referred to receiver input (dBm)

T_2 = D/U threshold for receiver noise (dB)

9. Calculation of System Performance Score (SPS)

The SPS is the single most significant program output. It enables the user to evaluate the overall

performance of the given system configuration in light of all significant interference interactions. An analysis of the factors determining the SPS will enable the user to make necessary adjustments in the configuration so that satisfactory performance may be obtained. Examples of this process will be provided in the next chapter which will evaluate the AN/URC-109 system as it is to be installed on the LHD-1. The SPS is calculated as follows:

$$SPS = \text{Prob}\ [D - U_1 > T_1 \text{ and } D - U_2 > T_2 \text{ and } \ldots \ldots D - U_n > T_n] \qquad 3.18$$

where

D = desired power (dBm)

U_1, U_2 = ambient noise and receiver noise (dBm)

T_1, T_2 = D/U thresholds for U_1 and U_2 (dB)

$U_3 \ldots U_n$ = PINO values for undesired transmitter signals (dBm)

$T_3 \ldots T_n$ = D/U thresholds for $U_3 \ldots U_n$ (dB)

Only the ten most severe interactions are used in calculating the SPS. In its execution, WIDEBAND generates a set of transmission states, each of which has an associated SPS. The overall SPS for the system is an average of the SPS's for each transmission state. The average is weighted by the transmitter duty cycles if the number of transmission states is small. It is unweighted if the number of states is large, because, in that case, WIDEBAND randomly generates the set of states using a Monte-Carlo technique [Ref. 7: p. 2-93].

D. PROGRAM OUTPUT

The output of the WIDEBAND program is very similar for both modes of operation. The first section of the output file is a tabulation of all the data input by the user in the run file. The second section is a table of spurious emission values, with associated rejection values, for each transmitter in the system. Following this is a table of EIL values, along with some other associated parameters. This table may be exhaustive if that option was selected in the run file. Otherwise, only the most significant interactions are included. The next section provides a listing of each transmission state, with associated significant interactions. If the transmission states are randomly generated, this section is omitted.

Following this are performance reports for each receiver in the system. These reports contain a listing of the significant receiver parameters such as bandwidth and sensitivity. They also contain the heart of the entire report: the major program output. This is either the system performance score or the necessary desired power, depending on the mode selected. The second part of the report contains another listing of the most severe interference interactions, listed in order of increasing IPS and in order of decreasing EIL. Antenna-to-antenna coupling losses, IEP, IPS, EIL, and duty cycle of the interaction are also included. The last

section of the receiver performance report is a power reduction table which shows what the improvement in SPS would be for incremental reductions in power for each transmitter. This permits a logical approach to power management if the interference problem warrants such action.

This completes the general discussion of the WIDEBAND program. The next section will begin the evaluation of the actual system installation for the LHD-1.

IV. LHD-1 PROGRAM INPUTS

A. THE DATA BASE

The data base for the LHD-1 wideband communication system installation was provided by the Naval Ocean Systems Center. It contains all four data files required to execute the WIDEBAND program. The data base contains records for both narrowband and wideband transmitters and receivers, although this study only utilizes the wideband components. Some of the more important data items contained in the records are listed below:

- Tuning Range: 2.000 - 28.000 MHz (Transmitter and Receiver)
- Receiver Sensitivity : -116 dBm
- Receiver Bandwidth: 0.0031 MHz
- Transmitter Power: 60 dBm

Since the data base was confirmed to be up to date by NOSC, and since equipment parameter generation was well beyond the scope of this project, the data base was used as provided.

B. THE RUN FILE

The key to success in executing the WIDEBAND program is the development of a run file which accurately reflects the configuration of the system to be evaluated, and correctly identifies the desired program output. In the development of the run file, numerous decisions must be made. Among these

are:

- what interaction types are to be considered.
- the coordinate system to be used for the antennas.
- what set of frequencies will be evaluated.
- the major program output desired (NDP or SPS).
- how many transmission states are to be generated.
- what constitutes acceptable system performance.
- what transmitter and receiver modulation types to use.

In the following sections, some of the key decisions which went into the development of the run file for the LHD-1 system evaluation will be discussed.

1. Antenna Coordinate System

WIDEBAND requires that antenna locations be entered in the form of x, y, and z coordinates. The origin and reference directions are selected by the user, however. For this study, the x-axis was chosen to be in the athwartships direction, with positive being to starboard. The y-axis was chosen to be the longitudinal axis, with positive being forward. The z-axis was chosen to be the vertical axis, with positive being upward. The origin was chosen to be the x-y coordinate of the 2-9 MHz transmit antenna at the vertical height of the 02-level. Table 3 provides the actual coordinates of all HF antennas.

2. Frequency Selection

In order for this study to verify the preliminary analysis conducted by NOSC, the frequency set chosen for this

TABLE 3

LHD-1 HF ANTENNA COORDINATES

ANTENNA DESIGNATOR	FUNCTION	COORDINATES X	Y	Z
1-1	WB Receive	-99.0	-282.6	0.0
1-2	WB Receive	37.8	-289.8	0.0
2-1	WB Transmit	0.0	0.0	99.0
2-2	WB Transmit	-15.3	30.6	34.0
2-3	NB Transmit	-97.2	261.0	0.0
2-4	NB Transmit	37.8	239.4	0.0

NOTES: Antenna 2-1 is the 2-9 MHz transmit antenna.
Antenna 2-2 is the 9-30 MHz transmit antenna.
Antennas 2-3 and 2-4 are narrowband antennas which are not part of the analysis, but are included for completeness.

evaluation was the same set which was used in the NOSC analysis. These frequencies are the same as those listed in Table 1. This set of frequencies was chosen as typical of operational frequency plans, and was submitted as an input to the FREE computer program which developed the IM-free sets shown in Table 1. As stated previously, if all twenty-three frequencies are used, third order intermodulation will be present. The receiver bandwidth was used as the guard band and a required frequency separation of 2.5% was specified.

Two of the frequencies in the set (3.266 MHz and 3.263 MHz) did not meet the 2.5% frequency separation criterion, but it was decide to use them in the initial program runs to permit WIDEBAND to verify their unacceptability. In the final program runs in which overall system performance was be evaluated, a different frequency was substituted.

3. Selection of Performance Score Targets

One of the key decisions that must be made when developing the WIDEBAND run files is what performance score target values to use. For this study, a target value of 0.9 was chosen for IPS, UPS, and SPS. This target value would mean that the system would have a 90% probability of operating satisfactorily. Alternatively, it could be considered that the target value represents a time availability of a particular receiver. In this case, the receiver could be considered to be available 90% of the time, given the operating conditions specified in the run file.

4. NDP Mode

a. Transmitter Power Selection

The program runs in the necessary desired power mode were made with a configuration consisting of one transmitter and twenty-two receivers. The transmitter power was chosen to be the maximum power that the system would support for a single transmitter (750 W). Since the NDP mode runs were to be made to evaluate each of the 506 possible paths, it was felt that the use of maximum available power would most clearly identify any possible interference problems.

b. Computation of Mean NDP

Each program run in the NDP mode would produce a set of necessary desired power levels. The necessary desired power for each receiver operating against each transmitter would thus be obtained. The mean necessary desired power

which would be used for each receiver in the SPS mode as a user input could then be obtained by averaging all of the NDP values obtained for each receiver.

c. Sample NDP Run File

Figure 7 illustrates one of the actual run files used during the NDP mode program runs. The transmitter is shown connected directly to the appropriate wideband transmit antenna. All twenty-two of the receivers are connected to a wideband nonlinear coupler, which is, in turn, connected to the wideband receive antenna. The D/U receiver threshold is specified. The D/U target values were obtained from Table 2-1 of Reference 2.

5. <u>SPS Mode</u>

a. Transmitter Power Selection

The program runs in the SPS mode were made using a configuration which consisted of one receiver operating against twenty-two transmitters. Transmitter power levels were selected so that the 6 kW power bank would be at maximum utilization. This resulted in each transmitter having a power output of either 375 W or 187.5 W. An attempt was made to assign the higher power level to those circuits likely to require the greatest range. Table 4 provides a listing of the power level and frequency assigned to each of the twenty-three HF circuits.

```
ID,'NECESSARY DESIRED POWER MODE PATHS 23-44'
EQ,22,1,0,1,0,6
OP,1,1,1,0,0,0,0,0,0,0,0,2,0,2,0,1
WB AN/URC-109
P1,6.,1,.9,0.9,.9,7,0,73
P2,0.,0.,6,50,1
TX,1,AN/URC-109,A,1,0,2.514,PG,58.75,C,5.6,.008
RX,1,AN/URC-109,N,1,0,9.397,PG,0.,6.,D/U,7.0,0
RX,2,AN/URC-109,N,1,0,3.263,PG,0.,6.,D/U,7.0,0
RX,3,AN/URC-109,N,1,0,16.167,A3A,0.,6.,D/U,8.0,0
RX,4,AN/URC-109,N,1,0,4.167,PG,0.,6.,D/U,7.0,0
RX,5,AN/URC-109,N,1,0,9.213,PG,0.,6.,D/U,7.0,0
RX,6,AN/URC-109,N,1,0,2.634,PG,0.,6.,D/U,7.0,0
RX,7,AN/URC-109,N,1,0,3.566,PG,0.,6.,D/U,7.0,0
RX,8,AN/URC-109,N,1,0,5.228,PG,0.,6.,D/U,7.0,0
RX,9,AN/URC-109,N,1,0,5.086,PG,0.,6.,D/U,7.0,0
RX,10,AN/URC-109,N,1,0,4.925,PG,0.,6.,D/U,7.0,0
RX,11,AN/URC-109,N,1,0,6.228,PG,0.,6.,D/U,7.0,0
RX,12,AN/URC-109,N,1,0,11.600,A3A,0.,6.,D/U,8.0,0
RX,13,AN/URC-109,N,1,0,19.604,F3A,0.,6.,D/U,11.0,0
RX,14,AN/URC-109,N,1,0,2.065,LINK11,0.,6.,D/U,27.0,0
RX,15,AN/URC-109,N,1,0,3.266,PG,0.,6.,D/U,7.0,0
RX,16,AN/URC-109,N,1,0,2.410,PG,0.,6.,D/U,7.0,0
RX,17,AN/URC-109,N,1,0,7.795,PG,0.,6.,D/U,7.0,0
RX,18,AN/URC-109,N,1,0,4.529,PG,0.,6.,D/U,7.0,0
RX,19,AN/URC-109,N,1,0,8.027,PG,0.,6.,D/U,7.0,0
RX,20,AN/URC-109,N,1,0,18.205,F3A,0.,6.,D/U,11.0,0
RX,21,AN/URC-109,N,1,0,12.465,PG,0.,6.,D/U,7.0,0
RX,22,AN/URC-109,N,1,0,22.419,F7A,0.,6.,D/U,12.0,0
NL,1,AN/URC-109,A,3,0
SA,1,A2-9,0.,0.,99.,V,-1.5,3.
SA,2,A9-30,-15.3,30.6,34.0,V,-1.5,3.
SA,3,ANT,-99.0,-282.6,0.0,V,-3.5,3.
SA,4,ANT,37.8,-289.8,0.0,V,-3.5,3.
SA,5,ANT,-97.2,261.0,0.0,V,-1.5,3.
SA,6,ANT,37.8,239.4,0.0,V,-1.5,3.
```

Figure 7. Sample NDP Run File

TABLE 4

LHD-1 HF CIRCUIT POWER LEVELS

CKT NO.	CIRCUIT DESIGNATION	PEP	FREQUENCY
1	Naval Gunfire Control	187.5	9.397
2	Landing Force Fire Support Coord	187.5	2.514
3	Conference Command Alfa	187.5	3.263
4	Beach Boat Control	375.0	16.167
5	Landing Force Command	187.5	4.167
6	Landing Force Tactical	375.0	9.213
7	Landing Force Intelligence	187.5	2.634
8	LF Artillery Command/Fire Direction	187.5	3.566
9	TF/TG Special Intelligence	187.5	5.228
10	Data Systems Administration	375.0	5.086
11	AAW Intersector C & R	375.0	4.925
12	Tactical Air Request	375.0	6.228
13	Landing Force Medical Regulations	187.5	11.600
14	TF/TG Operations/Administrative	375.0	19.604
15	LINK-11	187.5	2.065
16	Helicopter Request	187.5	3.266*
17	Tactical Air Command	187.5	2.410
18	FAAD Weapon Control	375.0	7.795
19	Landing Force HST Control	187.5	4.529
20	TF/TG Command	375.0	8.027
21	SI Coordination	375.0	18.205
22	HICOM	187.5	12.465
23	Primary Ship-to-Shore	375.0	22.419

NOTE:

* This frequency does not meet the 2.5% separation requirement, and was changed to 2.744 MHz following the initial run.

b. Sample SPS Run File

Figure 8 illustrates one of the actual run files used during the SPS mode program runs. As can be seen, twenty-two transmitters are operated against a single receiver. All of the transmitters are connected to linear couplers, which are connected to the appropriate transmit

antenna. The crest factor values were obtained from Table 3-1 of Reference 7. The necessary desired power specified for the receiver is that computed based on the NDP program runs, as discussed above. Modulation types were assigned based on the circuit type of the transmitter or receiver.

```
ID,'SPS MODE TRANS 2-23, RCVR 1'
EQ,1,22,2,1,0,6
OP,1,1,1,0,1,1,1,1,1,1,0,2,0,0,1
WB AN/URC-109
P1,6.,0,0.,0.,.9,7,0,73
P2,0.,0.,6,100,1
TX,1,AN/URC-109,C,1,0,2.514,PG,52.73,C,5.6,.008
TX,2,AN/URC-109,C,1,0,3.263,PG,52.73,C,5.6,.008
TX,3,AN/URC-109,C,2,0,16.167,A3A,55.74,C,10.0,.058
TX,4,AN/URC-109,C,1,0,4.167,PG,52.73,C,5.6,.033
TX,5,AN/URC-109,C,2,0,9.213,PG,55.74,C,5.6,.1
TX,6,AN/URC-109,C,1,0,2.634,PG,52.73,C,5.6,.025
TX,7,AN/URC-109,C,1,0,3.566,PG,52.73,C,5.6,.025
TX,8,AN/URC-109,C,1,0,5.228,PG,52.73,C,5.6,.042
TX,9,AN/URC-109,C,1,0,5.086,PG,55.74,C,5.6,.042
TX,10,AN/URC-109,C,1,0,4.925,PG,55.74,C,5.6,.033
TX,11,AN/URC-109,C,1,0,6.228,PG,55.74,C,5.6,.05
TX,12,AN/URC-109,C,2,0,11.600,A3A,52.73,C,10.0,.025
TX,13,AN/URC-109,C,2,0,19.604,F3A,55.74,C,0.0,1.0
TX,14,AN/URC-109,C,1,0,2.065,LINK11,52.73,C,8.3,1.0
TX,15,AN/URC-109,C,1,0,2.744,PG,52.73,C,5.6,.017
TX,16,AN/URC-109,C,1,0,2.410,PG,52.73,C,5.6,.008
TX,17,AN/URC-109,C,1,0,7.795,PG,55.74,C,5.6,.05
TX,18,AN/URC-109,C,1,0,4.529,PG,52.73,C,5.6,.033
TX,19,AN/URC-109,C,1,0,8.027,PG,55.74,C,5.6,.067
TX,20,AN/URC-109,C,2,0,18.205,F3A,55.74,C,0.0,.5
TX,21,AN/URC-109,C,2,0,12.465,PG,52.73,C,5.6,.025
TX,22,AN/URC-109,C,2,0,232.419,F7A,55.74,C,7.6,1.0
RX,1,AN/URC-109,N,1,0,9.397,PG,-108.64,6.,D/U,7.0,0
NL,1,AN/URC-109,A,3,0
CU,1,CUP,A,1,0
CU,2,CUP,A,2,0
SA,1,A2-9,0.,0.,99.,V,-1.5,3.
SA,2,A9-30,-15.3,30.6,34.0,V,-1.5,3.
SA,3,ANT,-99.0,-282.6,0.0,V,-3.5,3.
SA,4,ANT,37.8,-289.8,0.0,V,-3.5,3.
BC,CUP,0,3,0.,0.
```

Figure 8. Sample SPS Run File

V. WIDEBAND OUTPUT FOR THE LHD-1 INSTALLATION

A. METHODOLOGY

1. NDP Mode (First Run)

There were two primary objectives in undertaking the analysis of the AN/URC-109 system installation on the LHD-1. The first of these was to verify that no individual receiver would be excessively interfered with by any individual transmitter. In order to accomplish this verification, a matrix of RF coupling paths was developed. This matrix was composed of all possible combinations of single receivers versus single transmitters. With twenty-three circuits, and keeping in mind the fact that the receivers would not be paired with the transmitters on their own frequency, there were a total of 506 coupling paths.

In order to evaluate each receiver against each transmitter, 506 separate runs of the WIDEBAND program could have been run. It was decided, however, to input twenty-two receivers at a time, and evaluate them against the transmitter at the (twenty-third) remaining frequency. If this was done using the NDP mode, the mean necessary desired power could be obtained at the same time. Thus, a total of twenty-three program runs were made in the NDP mode. The interference interactions of interest were receiver adjacent signal

(RAS) and transmitter adjacent signal (TAS). The results will be discussed later in this chapter.

2. SPS Mode (Second Run)

The second primary objective was to evaluate the performance of each receiver, using the necessary desired power values obtained in the NDP mode runs. Each receiver would be evaluated against all twenty-two remaining transmitters. This required a total of twenty-three WIDEBAND runs in the SPS mode as well. The performance score targets were all set to 0.90. The program output of greatest interest was the SPS calculated for each receiver. If any particular receiver's SPS was below the predetermined limit, EIL and IPS values for the most severe interference interactions were also included as program outputs, permitting identification of the transmitters causing the most problems. Another program output, the power reduction table provides a listing of the effect on system performance of reducing the power incrementally for each transmitter.

B. INTERFERENCE INTERACTIONS

1. Acceptability Criteria

WIDEBAND provides a measure of the degree of interference in a given RF coupling path by providing the EIL and IPS values for each relevant interaction. As stated earlier, the EIL is the amount of additional losses necessary to reduce the PINO such that the IPS is equal to the target

value. Thus, positive EIL values indicate that the interference level for that particular path exceeds the level necessary to permit the attainment of the IPS. It was decided that EIL values of +3 dB or less would be acceptable. Any EIL above 3 dB would indicate a design deficiency with the system for that particular coupling path.

2. Paths With Unacceptable Interference Interactions

The initial program runs revealed that, with the frequency set listed in Table 1, two coupling paths had unacceptable interference levels. These were paths numbered 59 and 333. Path 59 was defined as a secure voice transmitter at a frequency of 3.263 MHz versus a secure voice receiver at a frequency of 3.266 MHz. Path 333 was defined as the reverse arrangement. As discussed earlier, these two frequencies did not meet the 2.5% minimum frequency separation criterion, and interference problems were expected. The receiver adjacent signal EIL was +93.9 dB and the transmitter adjacent signal EIL was +10.9 dB. All other coupling paths met the 3 dB maximum EIL criterion.

3. Possible Solutions

The most obvious solution to the interference problem discussed above was to replace one of the two frequencies such that the 2.5% separation requirement would be met. The circuit assigned a frequency of 3.266 MHz was reassigned to a frequency of 2.744 MHz. Although this frequency is not in the

IM-free set of frequencies listed in Table 1, it was used in the NOSC preliminary evaluation with acceptable results.

The entire set of NDP mode program runs was repeated using 2.744 MHz in place of 3.266 MHz. The EIL values for all coupling paths in this second set of program runs were acceptable. The RAS EIL values for paths 59 and 333 improved by over 125 dB to -31.8 dB. There were no EIL values greater than 0 dB. The necessary desired power values obtained in the repeated runs were essentially unchanged from the first set of runs. Table 5 provides a list of the mean necessary desired power levels obtained during the second set of NDP mode program runs. A complete listing of EIL and IPS values obtained in both sets of program runs is included as Appendix A.

C. SYSTEM PERFORMANCE

1. Acceptability Criteria

The performance score target selection was discussed earlier. It was felt that a 90% probability of satisfactory performance would be acceptable. The other key acceptability criteria for the SPS mode were the EIL and IEP for the most severe interactions in each of the receiver performance reports. With twenty-two transmitters being operated simultaneously against a single receiver, some high positive EIL values were expected. As was done in the NDP mode, a cutoff value of +3 dB was chosen for the EIL. The EIL alone,

TABLE 5

MEAN NECESSARY DESIRED POWER LEVELS

RECEIVER NUMBER	MEAN NECESSARY DESIRED POWER
1	-108.6 dBm
2	-105.8
3	-106.4
4	-108.4
5	-107.0
6	-108.6
7	-105.9
8	-106.7
9	-107.6
10	-107.5
11	-107.4
12	-107.9
13	-108.0
14	-105.7
15	-85.2
16	-106.0
17	-105.6
18	-108.3
19	-107.2
20	-108.4
21	-105.6
22	-109.1
23	-104.8

however, does not provide a complete picture of the severity of a given interaction. The system duty cycle, derived from the individual transmitter duty cycles, must be considered also. This is done in the form of the individual error probability (IEP). This value is a measure of how frequently the interference would be likely to occur. If the IEP is very low, the EIL value is probably not significant, no matter how high. For example, if a given interaction had an EIL of +12 dB, but an IEP of 0.001, the system performance would probably be satisfactory. The interference interaction causing the high EIL would have only a 0.1% probability of causing a problem.

Given the above information, it was decided that an EIL above +3 dB would only be considered unacceptable if it was combined with an IEP of 10% (.100) or higher. A high IEP alone is not significant if the EIL is below the cutoff level of 3 dB. Thus an interaction with an EIL of 2 dB and an IEP of 0.9 would be acceptable.

2. Evaluation of Receiver Performance

In this section, each of the individual receiver reports will be analyzed, and the receiver's performance will be evaluated. Although a performance score target of 90% was selected, since the system was being evaluated under worst-case conditions, actual performance scores within 10% of that target would be considered acceptable. The receiver performance evaluations follow.

Receiver 1 had only one interference interaction above the cutoff value. This was an FTIM interaction with transmitters 13, 14, and 21. The EIL was only slightly above cutoff at 3.7 dB. The IEP, however, was extremely low (.002), so the probability of the interference actually occurring is extremely low. The SPS was 0.84 which was considered satisfactory. Power reductions in transmitters 14, 15, and 23 would have resulted in approximately 1% improvement in SPS for each transmitter.

Receiver 2 also had only one interference interaction above cutoff. This was also an FTIM interaction with transmitters 22 and 23. The EIL was 18.6 dB, but again, the IEP was very low at only .018. The SPS was 0.85, and the receiver performance was considered satisfactory. Power reductions in transmitters 22 and 23 would have provided an improvement in the SPS of about 1% each.

Receiver 3 had one FTIM interaction above cutoff with transmitters 12, 14, 18, and 21. The EIL was 14.3 dB, but the IEP was sufficiently low (.001) for the interaction to be ignored. The SPS was 0.87, and no significant improvement would have been possible with power reductions.

Receiver 4 had two interactions above cutoff. The first was an FTIM with transmitters 12, 15, 18, 21, and 23. The EIL was 5.1 dB, but the IEP was listed as .000. The second interaction was an FTIM with transmitters 11, 14, and

21. The EIL was 4.4 dB and the IEP was .003. Again, these interactions were considered insignificant. The SPS was 0.84. 1% improvements in SPS would have been possible with power reductions in transmitters 14 and 23.

Receiver 5 also had two interactions above cutoff. The first was an FTIM with transmitters 12 and 15. The EIL was 28.5 dB and the IEP was .047. The second was an FTIM with transmitters 10, 12, and 14. The EIL was 6.0 dB and the IEP was .001. These were considered insignificant. The SPS was 0.83 and no significant improvement would have been possible with power reductions.

Receiver 6 had one of the worst performances of the lot with an SPS of only 81%. This was bordering on being unsatisfactory. Three interactions were above cutoff. The first was an FTIM with transmitters 14, 18, 21, and 23. The EIL was 17.6 dB and the IEP was .018. The second was an FTIM with transmitters 10 and 15. The EIL was 17.9 dB and the IEP was .029. The last was an FTIM with transmitters 12, 14, and 15. The EIL was 5.3 dB and the IEP was .012. There were seventeen interactions (4 FTIM and 13 TAS) which were within 10 dB of the cutoff, and this combination resulted in the relatively low SPS. Power reductions in transmitters 14 and 23 would have resulted in approximate 1% improvements in SPS, and a power reduction in transmitter 15 would have resulted in a nearly 2% improvement.

Receiver 7 had no interaction above cutoff, and with a performance score of 0.87, was considered completely satisfactory.

Receiver 8 was one of two receivers to have an unsatisfactory performance, with an SPS of 0.79. Contributing to the poor score were two interactions above cutoff and 18 interactions within 10 dB of cutoff. The first of the two interactions above cutoff was an FTIM with transmitters 6, 14, 18, and 23. The EIL was 7.6 dB and the IEP was .001. The second was an FTIM with transmitters 7, 15, 18, 21, and 23. The EIL was 4.7 dB and the IEP was also .001. The SPS for this receiver could have been significantly improved by power reduction. Reductions in transmitters 14 and 23 would have resulted in nearly 7% improvements in SPS and a reduction in transmitter 15 would have yielded a 4% improvement.

Receiver 9 had only one interaction above cutoff. It was an FTIM with transmitters 14, 20, and 21. The EIL was 18.2 dB and the IEP was .025. The SPS was considered satisfactory at 82%. Power reductions in transmitters 14 and 21 would have resulted in SPS improvements of about 2% each.

Receiver 10 was the other receiver to have an unsatisfactory performance, with an SPS of 79%. There were only two interactions above cutoff. The first was an FTIM with transmitters 6 and 15. The EIL was 16.8 dB and the IEP was .064. This was approaching our 10% limit closely enough to have probably made a significant reduction in the SPS.

The other interaction was an FTIM with transmitters 12, 14, and 15. The EIL was 4.2 dB and the IEP was .010. There were 18 interactions within 10 dB of cutoff. A power reduction in transmitter 15 would have resulted in an SPS improvement of 3.5%, and reductions in transmitters 6 and 14 would led to improvements of about 1% each.

Receiver 11 had no interactions above cutoff, and its performance was considered satisfactory. The SPS was 0.86.

Receiver 12 had one interaction above cutoff. It was an FTIM with transmitters 5 and 15. The EIL was 26.0 dB and the IEP was 0.030. The performance score was 0.85 which was considered satisfactory. SPS improvements of about 1% could have been obtained with power reductions in transmitters 14 and 23.

Receiver 13 had two interactions above cutoff. The first was an FTIM with transmitters 8 and 20. The EIL was 11.8 dB and the IEP was 0.001. The second interaction was an FTIM with transmitters 6, 18, and 23. The EIL was 3.54 dB and the IPS was also 0.001. These were not considered significant. The SPS was 0.84 which was considered satisfactory. SPS improvements of about 1% could have been obtained with power reductions in transmitters 14, 15, and 23.

Receiver 14 had no interactions above cutoff, and was considered satisfactory with an SPS of 0.86.

Receiver 15 had one interaction above cutoff which was an FTIM with transmitters 20, 21, and 23. The EIL was 5.5 dB and the IEP was 0.008. This was not considered significant. The SPS was 0.87. SPS improvements of about 1% could have been obtained by reducing the power incrementally in transmitters 20, 21, and 23.

Receiver 16 had no interactions above cutoff, and was considered satisfactory with an SPS of 0.87.

Receiver 17 was considered borderline with an SPS of 0.81. It had three interactions above cutoff. The first was an FTIM with transmitters 9, 14, and 23. The EIL was 29.6 dB and the IEP was 0.040. The second was an FTIM with transmitters 14, 20, and 23. The EIL was 14.8 dB and the IEP was 0.019. The last was an FTIM with transmitters 13, 14, 18, and 21. The EIL was 7.8 dB and the IEP was 0.000. The first of these was probably the primary contributor to the low SPS. Power reductions in transmitters 14, 20, 21, and 23 would have resulted in approximate 1% improvements in SPS.

Receiver 18 was also considered borderline with an SPS of 0.80. There were two interactions above cutoff. The first was an FTIM with transmitters 6, 14, 21, and 23. The EIL was 17.3 dB and the IEP was 0.035. The second was an FTIM with transmitters 8, 14, 15, and 21. The EIL was 4.2 dB and the IEP was 0.003. AN SPS improvement of about 3% could have been obtained with a power reduction in transmitter 14.

and improvements of about 2% with reductions in transmitters 21 and 23.

Receiver 19 had one interaction above cutoff. It was an FTIM with transmitters 9, 11, and 14. The EIL was 6.7 dB and the IEP was 0.000. This, obviously, was not considered significant. The SPS was considered satisfactory at 0.86, although 1% improvements could have been obtained by reducing the power of transmitters 14 and 23.

Receiver 20 had two interactions above cutoff. The first was an FTIM with transmitters 10 and 21. The EIL was 21.4 dB and the IEP was 0.017. The second was an FTIM with transmitters 9, 14, and 21. The EIL was 14.7 dB and the IEP was 0.013. The SPS was considered satisfactory at 0.84. SPS improvements of about 1% could have been obtained with power reductions in transmitters 14, 21, and 23.

Receiver 21 had no interactions above cutoff, and was considered satisfactory with an SPS of 0.85.

Receiver 22 had one interaction above cutoff. It was an FTIM with transmitters 8 and 14. The EIL was 11.5 dB and the IEP was 0.011. The SPS was considered satisfactory at 0.82. An SPS improvement of nearly 2% could have been obtained with a power reduction in transmitter 14, and 1% improvements with reductions in transmitters 6, 15, 21, and 23.

Receiver 23 had one interaction above cutoff. It was an FTIM with transmitters 15, 20, and 21. The EIL was 4.8

and the IEP was 0.007. The SPS was considered satisfactory at 0.86. SPS improvements of about 1% could have been obtained by reducing power in transmitters 14, 15, 20, and 21.

3. Evaluation of Overall System Performance

The overall performance of the system under the worst-case conditions imposed was considered to be satisfactory. Although two of the receivers did not meet the arbitrary lower SPS limit, and a few more were borderline, the average performance score was about 84% which was considered quite good considering that each receiver was being evaluated against twenty-two transmitters simultaneously.

A more realistic scenario would be one in which the system was operating with five circuits transmitting simultaneously. A typical case where a maximum of five circuits were transmitting was selected, with a representative mix of circuit types, and the system was reevaluated in the SPS mode with that configuration. Table 6 shows the results. The SPS values uniformly improved to near the selected target value of 0.90. The average performance score was about 0.88. This clearly indicates that the system will perform satisfactorily under normal operating conditions, and will probably perform satisfactorily under worst-case conditions. It is significant to note that the circuits with a high duty cycle, such as LINK-11, uniformly had performance scores near the target

TABLE 6

SYSTEM PERFORMANCE WITH FIVE CIRCUITS TRANSMITTING

CIRCUIT NUMBER	PERFORMANCE SCORE
15	0.89
19	0.88
20	0.87
21	0.87
23	0.88

value. The circuits which performed the most poorly all had duty cycles of 0.5 or less. This would tend to improve the confidence level in the system, since the circuits which are active nearly all the time performed well.

It should be noted that, although WIDEBAND indicates that this system will perform satisfactorily as designed, real validating measurements must be taken to verify the program's results.

VI. SUBJECTIVE EVALUATION OF WIDEBAND

A. ESTABLISHMENT OF THE DATA BASE

The most complex and difficult aspect of working with WIDEBAND is the establishment of the data base. The compilation of the equipment parameter file, the generalized data file, the degradation curve parameter file, and the coupler/decoupler file requires a considerable effort. There is an entire volume of the COSAM II User's Manual which is dedicated to equipment parameter generation. Fortunately, the WIDEBAND data base needs only be established once for each equipment configuration.

WIDEBAND has a complementary program called COSMAIN which is used to maintain the data base once it is established. With this program, it is very easy to add or delete records from the various data base files. It is also possible to print out the table of contents of each file, as well as printing out the actual data records. Once a library of equipment parameter "cards" is established, the data base files for any given installation can be put together quite simply by adding the appropriate records.

B. EASE OF DATA HANDLING

After the data base is established, the user is only concerned with manipulating the various run file cards in

order to obtain the exact system configuration desired. The run file is structured so that a minimum of changes is necessary in order to make any desired changes in equipment configuration. For example, there is a receiver selection card which permits the user to select subsets of receivers for program evaluation. If WIDEBAND predicted that only two of twenty receivers would have unsatisfactory performance, the receiver selection card would permit changes that would only affect those specific receivers.

The run file cards are structured in a logical and easy to understand format. The first entry always identifies the type of input data card. Succeeding entries follow a natural sequence of presenting the required data items. Only those cards which pertain to the specific configuration being evaluated need to be included in the run deck. Although the card entries may appear cryptic, the user's manual provides a very concise description of each entry.

C. UTILITY OF THE USER'S MANUAL

Reference 7 is the WIDEBAND User's Manual. This document contains essentially all of the information that a user needs in order to successfully use WIDEBAND in the analysis of a communication system. It is laid out in a most useful and understandable manner. The manual starts out with a glossary of all of the acronyms and symbols used within. This was found to be most useful. Section 1 is a thorough introduction

to the WIDEBAND program which explains its purpose, discusses the various interference interaction models, describes the modes of operation, and lists the program's capabilities and limitations.

Section 2 provides a detailed description of the program, including a description of the four data base files, with examples of the records contained in each file type. It then goes on to discuss each of the algorithms which WIDEBAND uses to calculate undesired power levels and the various performance score data.

Section 3 describes the WIDEBAND program input. Each of the run file card types are described in detail, with each entry being thoroughly discussed. Recommended values of certain parameters (antenna gain and crest factor, for example) are given. This section is probably the key to being able to use WIDEBAND successfully. Since the data base is user-transparent once established, the run file contains all of the required data for the program to evaluate the given system. The fact that this section of the manual is so clearly written is, therefore, of particular significance.

Section 4 discusses the program's output. Each section of the output data file is discussed, and examples are provided of each type of output report. No attempt is made to discuss interpretation of the output data, however. It is assumed that the user's expertise, combined with the

background information provided in Section 2, would be sufficient to interpret the results properly.

Section 5 provides some information concerning the actual running of the program. The example provided relates to execution on the Sperry 1100 computer, which was not found to be useful, since the VAX-11 was used in this study.

The final section provides a sample problem which illustrates all aspects of running the program. A sample run file is provided, and the various output reports are discussed with a small degree of data interpretation being done.

D. OUTPUT DATA USABILITY

The format of the output data file was found to be most useful and easy to interpret. It was found to be very helpful to have all of the data from the run file organized and tabulated at the beginning of the output file. This enabled verification of critical input data such as frequency and power level, and resulted in greater confidence in the output data. The receiver reports were well organized and understandable. All of the key output data items, such as the mean ambient noise, mean receiver noise, mean desired signal, and performance scores were all presented together in a single page of the report.

The one area in which problems were encountered was that of obtaining a hard copy of the program output file. The code

was written to send the program output to the console, with no disk file being made. This was, obviously, not satisfactory. In order to obtain a disk file of the output data, the VAX output was assigned to a disk filespec. This technique produced acceptable disk files, but there was some data formatting problem which caused the line printer to trip off the line repeatedly when the output data file was sent to the printer. This was overcome by transmitting the output data file to the IBM mainframe and printing it out on the high speed printer. The FORTRAN code could undoubtedly have been modified to correct the problem, but WIDEBAND is a very large program, containing approximately 200 separate FORTRAN subprograms. The reprogramming task was beyond the scope of this project.

VII. SUMMARY AND RECOMMENDATIONS

A. SUMMARY

The purpose of this study was to evaluate the performance of the AN/URC-109 HF Wideband Communication System as it is to be installed on the LHD-1 Amphibious Assault Ship. The system is configured so that as many as twenty-two HF transmitters can be operated simultaneously. The transmitters must be assigned frequencies which are separated by at least 2.5%, and, as nearly as possible, are intermodulation free to at least the third order. The transmitter power levels must be selected so that their combined total does not exceed the system power bank maximum of 6 kW.

The evaluation was conducted by first running the WIDE-BAND program in the necessary desired power (NDP) mode to determine if any of the 506 possible RF coupling paths would have unsatisfactory levels of interference. At the same time, the necessary desired power level required for each receiver to meet its performance score target of 0.90 was determined. Once this data was obtained, the program was run in the system performance score (SPS) mode with twenty-two transmitters operating against a single receiver in order to obtain the receiver performance scores under worst-case conditions.

During the first program runs in the NDP mode, it was discovered that two of the frequencies in the frequency set selected did not meet the 2.5% separation criterion. This resulted in the RF coupling paths containing those two frequencies having unsatisfactory interference levels. One of the two was replaced by another frequency which met the 2.5% separation requirement, but was not in the intermodulation-free set like the others. The NDP mode runs were redone, with the result that all coupling paths had satisfactory interference levels.

The SPS mode program runs were made with the modified frequency set. The receiver performance scores obtained are listed in Table 7. Although the target performance score was 0.90, it was decided that scores in the range 0.80 to 0.90 would be acceptable. Two of the receivers, numbers 8 and 10, fell just short of this range with performance scores of 0.79. It was found that, with power reductions in the interfering transmitters, the performance scores could be brought up to acceptable levels. The average performance score for the overall system was found to be 0.84, which was considered to be satisfactory.

B. RECOMMENDATIONS

1. Program Output Direction

The WIDEBAND program should be modified so that the user can select where the output data file is to go. This

TABLE 7

SUMMARY OF RECEIVER PERFORMANCE SCORES

CIRCUIT NUMBER	PERFORMANCE SCORE (SPS)
1	0.84
2	0.85
3	0.87
4	0.84
5	0.83
6	0.81
7	0.87
8	0.79
9	0.82
10	0.79
11	0.86
12	0.85
13	0.84
14	0.86
15	0.87
16	0.87
17	0.81
18	0.80
19	0.86
20	0.84
21	0.85
22	0.82
23	0.86

should be a relatively simple modification of the FORTRAN files. The selection could be made as part of the input run file, or could be an interactive procedure prior to the start of actual program execution.

2. Frequency Planning

As discussed earlier, proper frequency planning is crucial to the successful operation of a wideband communication system. Every effort should be made to obtain frequency sets which are intermodulation-free to at least the third order. This can be accomplished by use of the FREE computer program, and careful advance planning. The minimum 2.5% frequency separation is also essential to successful operation.

3. Use of Minimum Power Required

In order to reduce intermodulation levels, circuits should be restricted to the minimum power levels which will provide the necessary range for the communications link. These levels can easily be calculated by ship's force personnel. Although the system has a high probability of successful operation at full load, a power reserve would be desirable both as a contingency for added requirements and as insurance for continued satisfactory performance.

4. System Coordinator Concept

It is recommended that a system coordinator be assigned whose duty it would be to monitor the performance of the system and to make necessary decisions with regard to power reductions, frequency changes, or duty cycle changes.

If the operational environment became such that interference was likely, the system coordinator could take on the role of a transmission clearinghouse for non-essential transmissions. Critical circuits, such as LINK-11, would take precedence over less important circuits, such as Landing Force Medical Regulations. The critical circuits would be free to transmit at any time, whereas the less critical circuits would have to obtain clearance from the system coordinator prior to transmitting. This would not be necessary under normal operating conditions, but could be used when the system began to approach its load limit.

5. Customization of WIDEBAND for Shipboard Use

The final recommendation is that the WIDEBAND program be customized for shipboard use. The program could be made interactive so that the system operators could easily enter the daily communications plan. The equipment configuration and data base would remain unchanged on a day-to-day basis. The program could then be used to evaluate how the system would perform with the given circuit loading and frequency assignments. The communications supervisor could make any necessary decisions regarding power reductions, frequency changes, etc. This would permit maximum flexibility in system operation, and still ensure adequate performance levels.

APPENDIX A

RF COUPLING PATHS WITH INTERFERENCE LEVELS
(ORIGINAL FREQUENCY SET)

Path	Rcvr No.	Xmtr No.	RAS EIL (dB)	RAS IPS	TAS EIL (dB)	TAS IPS
001	2	1	-76.90	1.00	-7.33	0.98
002	3	1	-74.21	1.00	-6.85	0.98
003	4	1	-72.90	1.00	-3.37	0.95
004	5	1	-70.84	1.00	-6.45	0.98
005	6	1	-11.28	0.99	1.26	0.87
006	7	1	-76.47	1.00	-7.24	0.98
007	8	1	-73.11	1.00	-6.70	0.98
008	9	1	-66.40	1.00	-6.13	0.98
009	10	1	-67.04	1.00	-6.17	0.98
010	11	1	-67.75	1.00	-6.21	0.98
011	12	1	-61.28	1.00	-5.91	0.98
012	13	1	-53.90	1.00	-3.78	0.96
013	14	1	-79.78	1.00	-4.30	0.96
014	15	1	-67.48	1.00	-7.71	0.99
015	16	1	-74.20	1.00	-6.85	0.98
016	17	1	-77.29	1.00	-7.41	0.99
017	18	1	-49.04	1.00	-5.67	0.98
018	19	1	-69.40	1.00	-6.33	0.98
019	20	1	-46.27	1.00	-5.63	0.98
020	21	1	-77.31	1.00	-3.59	0.96
021	22	1	-59.52	1.00	-3.68	0.96
022	23	1	-83.86	1.00	-4.73	0.97
023	1	2	-74.23	1.00	-4.08	0.96
024	3	2	-38.09	1.00	-6.85	0.98
025	4	2	-85.33	1.00	-3.37	0.95
026	5	2	-51.19	1.00	-6.45	0.98
027	6	2	-73.80	1.00	-4.12	0.96
028	7	2	-6.96	0.97	-5.26	0.97
029	8	2	-43.74	1.00	-6.70	0.98
030	9	2	-59.25	1.00	-6.13	0.98
031	10	2	-58.38	1.00	-6.17	0.98
032	11	2	-57.34	1.00	-6.21	0.98
033	12	2	-64.31	1.00	-5.91	0.98
034	13	2	-78.72	1.00	-3.78	0.96
035	14	2	-88.99	1.00	-4.30	0.96
036	15	2	-19.41	1.00	-7.71	0.99
037	16	2	-38.15	1.00	-6.85	0.98
038	17	2	-3.87	0.96	-4.51	0.97
039	18	2	-69.98	1.00	-5.67	0.98
040	19	2	-54.42	1.00	-6.33	0.98

041	20	2	-70.66	1.00	-5.63	0.98
042	21	2	-87.59	1.00	-3.59	0.96
043	22	2	-80.18	1.00	-3.68	0.96
044	23	2	-91.50	1.00	-4.73	0.97
045	1	3	-72.46	1.00	-4.08	0.96
046	2	3	-39.01	1.00	-7.33	0.98
047	4	3	-84.57	1.00	-3.37	0.95
048	5	3	-40.96	1.00	-6.45	0.98
049	6	3	-71.97	1.00	-4.12	0.96
050	7	3	-35.86	1.00	-7.24	0.98
051	8	3	-22.42	1.00	-6.70	0.98
052	9	3	-53.88	1.00	-6.13	0.98
053	10	3	-52.65	1.00	-6.17	0.98
054	11	3	-51.12	1.00	-6.21	0.98
055	12	3	-60.64	1.00	-5.91	0.98
056	13	3	-77.45	1.00	-3.78	0.96
057	14	3	-88.44	1.00	-4.30	0.96
058	15	3	-36.62	1.00	-7.71	0.99
059	16	3	93.86	0.00	10.86	0.48
060	17	3	-41.39	1.00	-7.41	0.99
061	18	3	-67.55	1.00	-5.67	0.98
062	19	3	-46.59	1.00	-6.33	0.98
063	20	3	-68.35	1.00	-5.63	0.98
064	21	3	-86.97	1.00	-3.59	0.96
065	22	3	-79.05	1.00	-3.68	0.96
066	23	3	-91.05	1.00	-4.73	0.97
067	1	4	-78.11	1.00	-4.08	0.96
068	2	4	-93.21	1.00	-7.33	0.98
069	3	4	-91.53	1.00	-6.85	0.98
070	5	4	-89.67	1.00	-6.45	0.98
071	6	4	-78.61	1.00	-4.12	0.96
072	7	4	-92.93	1.00	-7.24	0.98
073	8	4	-90.90	1.00	-6.70	0.98
074	9	4	-87.55	1.00	-6.13	0.98
075	10	4	-87.83	1.00	-6.17	0.98
076	11	4	-88.16	1.00	-6.21	0.98
077	12	4	-85.52	1.00	-5.91	0.98
078	13	4	-70.97	1.00	-3.78	0.96
079	14	4	-65.39	1.00	-4.30	0.96
080	15	4	-94.32	1.00	-7.71	0.99
081	16	4	-91.53	1.00	-6.85	0.98
082	17	4	-93.47	1.00	-7.41	0.99
083	18	4	-82.12	1.00	-5.67	0.98
084	19	4	-88.94	1.00	-6.33	0.98
085	20	4	-81.57	1.00	-5.63	0.98
086	21	4	-56.42	1.00	-3.59	0.96
087	22	4	-67.23	1.00	-3.68	0.96
088	23	4	-75.61	1.00	-4.73	0.97
089	1	5	-69.91	1.00	-4.08	0.96
090	2	5	-52.92	1.00	-7.33	0.98
091	3	5	-41.77	1.00	-6.85	0.98

092	4	5	-83.52	1.00	-3.37	0.95
093	6	5	-69.32	1.00	-4.12	0.96
094	7	5	-51.50	1.00	-7.24	0.98
095	8	5	-34.48	1.00	-6.70	0.98
096	9	5	-43.42	1.00	-6.13	0.98
097	10	5	-41.00	1.00	-6.17	0.98
098	11	5	-37.74	1.00	-6.21	0.98
099	12	5	-54.55	1.00	-5.91	0.98
100	13	5	-75.67	1.00	-3.78	0.96
101	14	5	-87.66	1.00	-4.30	0.96
102	15	5	-46.57	1.00	-7.71	0.99
103	16	5	-41.72	1.00	-6.85	0.98
104	17	5	-54.10	1.00	-7.41	0.99
105	18	5	-63.91	1.00	-5.67	0.98
106	19	5	-25.13	1.00	-6.33	0.98
107	20	5	-64.92	1.00	-5.63	0.98
108	21	5	-86.10	1.00	-3.59	0.96
109	22	5	-77.47	1.00	-3.68	0.96
110	23	5	-90.43	1.00	-4.73	0.97
111	1	6	-11.24	0.99	1.10	0.87
112	2	6	-76.43	1.00	-7.33	0.98
113	3	6	-73.68	1.00	-6.85	0.98
114	4	6	-73.36	1.00	-3.37	0.95
115	5	6	-70.22	1.00	-6.45	0.98
116	7	6	-76.00	1.00	-7.24	0.98
117	8	6	-72.55	1.00	-6.70	0.98
118	9	6	-65.61	1.00	-6.13	0.98
119	10	6	-66.28	1.00	-6.17	0.98
120	11	6	-67.02	1.00	-6.21	0.98
121	12	6	-60.24	1.00	-5.91	0.98
122	13	6	-55.29	1.00	-3.78	0.96
123	14	6	-80.09	1.00	-4.30	0.96
124	15	6	-67.04	1.00	-7.71	0.99
125	16	6	-73.67	1.00	-6.85	0.98
126	17	6	-76.82	1.00	-7.41	0.99
127	18	6	-46.92	1.00	-5.67	0.98
128	19	6	-68.73	1.00	-6.33	0.99
129	20	6	-43.77	1.00	-5.63	0.98
130	21	6	-77.67	1.00	-3.59	0.96
131	22	6	-60.53	1.00	-3.68	0.96
132	23	6	-84.11	1.00	-4.73	0.97
133	1	7	-73.96	1.00	-4.08	0.96
134	2	7	-7.12	0.98	-5.35	0.97
135	3	7	-35.10	1.00	-6.85	0.98
136	4	7	-85.21	1.00	-3.37	0.95
137	5	7	-49.92	1.00	-6.45	0.98
138	6	7	-73.52	1.00	-4.12	0.96
139	8	7	-41.69	1.00	-6.70	0.98
140	9	7	-58.51	1.00	-6.13	0.98
141	10	7	-57.60	1.00	-6.17	0.98
142	11	7	-56.49	1.00	-6.21	0.98

143	12	7	-63.78	1.00	-5.91	0.98
144	13	7	-78.53	1.00	-3.78	0.96
145	14	7	-88.91	1.00	-4.30	0.96
146	15	7	-23.55	1.00	-7.71	0.99
147	16	7	-35.18	1.00	-6.85	0.98
148	17	7	-18.05	1.00	-7.34	0.98
149	18	7	-69.62	1.00	-5.67	0.98
150	19	7	-53.39	1.00	-6.33	0.98
151	20	7	-70.32	1.00	-5.63	0.98
152	21	7	-87.50	1.00	-3.59	0.96
153	22	7	-80.01	1.00	-3.68	0.96
154	23	7	-91.43	1.00	-4.73	0.97
155	1	8	-71.66	1.00	-4.08	0.96
156	2	8	-44.97	1.00	-7.33	0.98
157	3	8	-22.72	1.00	-6.85	0.98
158	4	8	-84.24	1.00	-3.37	0.95
159	5	8	-33.97	1.00	-6.45	0.98
160	6	8	-71.14	1.00	-4.12	0.96
161	7	8	-42.75	1.00	-7.24	0.98
162	9	8	-51.06	1.00	-6.13	0.98
163	10	8	-49.58	1.00	-6.17	0.98
164	11	8	-47.71	1.00	-6.21	0.98
165	12	8	-58.85	1.00	-5.91	0.98
166	13	8	-76.88	1.00	-3.78	0.96
167	14	8	-88.19	1.00	-4.30	0.96
168	15	8	-40.60	1.00	-7.71	0.99
169	16	8	-22.54	1.00	-6.85	0.98
170	17	8	-46.72	1.00	-7.41	0.99
171	18	8	-66.43	1.00	-5.67	0.98
172	19	8	-41.93	1.00	-6.33	0.98
173	20	8	-67.29	1.00	-5.63	0.98
174	21	8	-86.69	1.00	-3.59	0.96
175	22	8	-78.54	1.00	-3.68	0.96
176	23	8	-90.85	1.00	-4.73	0.97
177	1	9	-66.18	1.00	-4.08	0.96
178	2	9	-61.70	1.00	-7.33	0.98
179	3	9	-55.41	1.00	-6.85	0.98
180	4	9	-82.12	1.00	-3.37	0.95
181	5	9	-44.14	1.00	-6.45	0.98
182	6	9	-65.43	1.00	-4.12	0.96
183	7	9	-60.80	1.00	-7.24	0.98
184	8	9	-52.29	1.00	-6.70	0.98
185	10	9	-8.86	0.98	-3.56	0.96
186	11	9	-22.06	1.00	-6.18	0.98
187	12	9	-42.22	1.00	-5.91	0.98
188	13	9	-73.20	1.00	-3.78	0.96
189	14	9	-86.62	1.00	-4.30	0.96
190	15	9	-53.83	1.00	-7.71	0.99
191	16	9	-55.38	1.00	-6.85	0.98
192	17	9	-62.48	1.00	-7.41	0.99
193	18	9	-58.11	1.00	-5.67	0.98

194	19	9	-36.71	1.00	-6.33	0.98
195	20	9	-59.55	1.00	-5.63	0.98
196	21	9	-84.93	1.00	-3.59	0.96
197	22	9	-25.29	1.00	-3.68	0.96
198	23	9	-89.58	1.00	-4.73	0.97
199	1	10	-66.73	1.00	-4.08	0.96
200	2	10	-60.75	1.00	-7.33	0.98
201	3	10	-54.09	1.00	-6.85	0.98
202	4	10	-82.32	1.00	-3.37	0.95
203	5	10	-41.63	1.00	-6.45	0.98
204	6	10	-66.01	1.00	-4.12	0.96
205	7	10	-59.80	1.00	-7.24	0.98
206	8	10	-50.72	1.00	-6.70	0.98
207	9	10	-8.78	0.98	-3.70	0.96
208	11	10	-11.09	0.99	-4.51	0.97
209	12	10	-44.50	1.00	-5.91	0.98
210	13	10	-73.56	1.00	-3.78	0.96
211	14	10	-86.77	1.00	-4.30	0.96
212	15	10	-53.02	1.00	-7.71	0.99
213	16	10	-54.06	1.00	-6.85	0.98
214	17	10	-61.56	1.00	-7.41	0.99
215	18	10	-59.02	1.00	-5.67	0.98
216	19	10	-32.76	1.00	-6.33	0.98
217	20	10	-60.38	1.00	-5.63	0.98
218	21	10	-85.10	1.00	-3.59	0.96
219	22	10	-75.61	1.00	-3.68	0.96
220	23	10	-89.70	1.00	-4.73	0.97
221	1	11	-67.34	1.00	-4.08	0.96
222	2	11	-59.60	1.00	-7.33	0.98
223	3	11	-52.46	1.00	-6.85	0.98
224	4	11	-82.54	1.00	-3.37	0.95
225	5	11	-38.26	1.00	-6.45	0.98
226	6	11	-66.65	1.00	-4.12	0.96
227	7	11	-58.60	1.00	-7.24	0.98
228	8	11	-48.75	1.00	-6.70	0.98
229	9	11	-21.87	1.00	-6.13	0.98
230	10	11	-10.99	0.99	-4.63	0.97
231	12	11	-46.75	1.00	-5.91	0.98
232	13	11	-73.95	1.00	-3.78	0.96
233	14	11	-86.93	1.00	-4.30	0.96
234	15	11	-52.04	1.00	-7.71	0.99
235	16	11	-52.43	1.00	-6.85	0.98
236	17	11	-60.46	1.00	-7.41	0.99
237	18	11	-59.99	1.00	-5.67	0.98
238	19	11	-26.83	1.00	-6.33	0.98
239	20	11	-61.28	1.00	-5.63	0.98
240	21	11	-85.28	1.00	-3.59	0.96
241	22	11	-75.95	1.00	-3.68	0.96
242	23	11	-89.84	1.00	-4.73	0.97
243	1	12	-61.58	1.00	-4.08	0.96
244	2	12	-67.28	1.00	-7.33	0.98

245	3	12	-62.68	1.00	-6.85	0.98
246	4	12	-80.61	1.00	-3.37	0.95
247	5	12	-55.78	1.00	-6.45	0.98
248	6	12	-60.58	1.00	-4.12	0.96
249	7	12	-66.59	1.00	-7.24	0.98
250	8	12	-60.59	1.00	-6.70	0.98
251	9	12	-42.74	1.00	-6.13	0.98
252	10	12	-45.10	1.00	-6.17	0.98
253	11	12	-47.46	1.00	-6.21	0.98
254	13	12	-80.39	1.00	-3.78	0.96
255	14	12	-85.52	1.00	-4.30	0.96
256	15	12	-58.74	1.00	-7.71	0.99
257	16	12	-62.66	1.00	-6.85	0.98
258	17	12	-67.88	1.00	-7.41	0.99
259	18	12	-49.72	1.00	-5.67	0.98
260	19	12	-52.24	1.00	-6.33	0.98
261	20	12	-52.05	1.00	-5.63	0.98
262	21	12	-83.69	1.00	-3.59	0.96
263	22	12	-72.87	1.00	-3.68	0.96
264	23	12	-88.70	1.00	-4.73	0.97
265	1	13	-58.64	1.00	-4.08	0.96
266	2	13	-86.13	1.00	-7.33	0.98
267	3	13	-83.94	1.00	-6.85	0.98
268	4	13	-70.50	1.00	-3.37	0.95
269	5	13	-81.35	1.00	-6.45	0.98
270	6	13	-60.07	1.00	-4.12	0.96
271	7	13	-85.78	1.00	-7.24	0.98
272	8	13	-83.07	1.00	-6.70	0.98
273	9	13	-78.16	1.00	-6.13	0.98
274	10	13	-78.61	1.00	-6.17	0.98
275	11	13	-79.10	1.00	-6.21	0.98
276	12	13	-74.84	1.00	-5.91	0.98
277	14	13	-79.99	1.00	-4.30	0.96
278	15	13	-87.52	1.00	-7.71	0.99
279	16	13	-83.93	1.00	-6.85	0.98
280	17	13	-86.45	1.00	-7.41	0.99
281	18	13	-68.43	1.00	-5.67	0.98
282	19	13	-80.28	1.00	-6.33	0.98
283	20	13	-67.28	1.00	-5.63	0.98
284	21	13	-76.75	1.00	-3.59	0.96
285	22	13	-42.02	1.00	-3.68	0.96
286	23	13	-85.08	1.00	-4.73	0.97
287	1	14	-76.37	1.00	-4.08	0.96
288	2	14	-88.25	1.00	-7.33	0.98
289	3	14	-86.77	1.00	-6.85	0.98
290	4	14	-56.77	1.00	-3.37	0.95
291	5	14	-85.18	1.00	-6.45	0.98
292	6	14	-76.72	1.00	-4.12	0.96
293	7	14	-88.01	1.00	-7.24	0.98
294	8	14	-86.23	1.00	-6.70	0.98
295	9	14	-83.43	1.00	-6.13	0.98

296	10	14	-83.66	1.00	-6.17	0.98
297	11	14	-83.93	1.00	-6.21	0.98
298	12	14	-81.81	1.00	-5.91	0.98
299	13	14	-71.84	1.00	-3.78	0.96
300	15	14	-89.25	1.00	-7.71	0.99
301	16	14	-86.77	1.00	-6.85	0.98
302	17	14	-88.48	1.00	-7.41	0.99
303	18	14	-79.23	1.00	-5.67	0.98
304	19	14	-84.58	1.00	-6.33	0.98
305	20	14	-78.82	1.00	-5.63	0.98
306	21	14	-41.06	1.00	-3.59	0.96
307	22	14	-69.75	1.00	-3.68	0.96
308	23	14	-52.95	1.00	-4.73	0.97
309	1	15	-77.85	1.00	-4.08	0.96
310	2	15	-32.46	1.00	-7.33	0.98
311	3	15	-48.75	1.00	-6.85	0.98
312	4	15	-88.42	1.00	-3.37	0.95
313	5	15	-57.88	1.00	-6.45	0.98
314	6	15	-77.45	1.00	-4.12	0.96
315	7	15	-36.44	1.00	-7.24	0.98
316	8	15	-52.43	1.00	-6.70	0.98
317	9	15	-64.43	1.00	-6.13	0.98
318	10	15	-63.70	1.00	-6.17	0.98
319	11	15	-62.83	1.00	-6.21	0.98
320	12	15	-68.82	1.00	-5.91	0.98
321	13	15	-82.08	1.00	-3.78	0.96
322	14	15	-91.97	1.00	-4.30	0.96
323	16	15	-48.79	1.00	-6.85	0.98
324	17	15	-28.02	1.00	-7.41	0.99
325	18	15	-73.92	1.00	-5.67	0.98
326	19	15	-60.43	1.00	-6.33	0.98
327	20	15	-74.54	1.00	-5.63	0.98
328	21	15	-90.61	1.00	-3.59	0.96
329	22	15	-83.47	1.00	-3.68	0.96
330	23	15	-94.41	1.00	-4.73	0.97
331	1	16	-72.45	1.00	-4.08	0.96
332	2	16	-39.08	1.00	-7.33	0.98
333	3	16	93.86	0.00	10.86	0.48
334	4	16	-84.57	1.00	-3.37	0.95
335	5	16	-40.09	1.00	-6.45	0.98
336	6	16	-71.96	1.00	-4.12	0.96
337	7	16	-35.95	1.00	-7.24	0.98
338	8	16	-22.25	1.00	-6.70	0.98
339	9	16	-53.86	1.00	-6.13	0.98
340	10	16	-52.62	1.00	-6.17	0.98
341	11	16	-51.09	1.00	-6.21	0.98
342	12	16	-60.62	1.00	-5.91	0.98
343	13	16	-77.44	1.00	-3.78	0.96
344	14	16	-88.43	1.00	-4.30	0.96
345	15	16	-36.67	1.00	-7.71	0.99
346	17	16	-41.45	1.00	-7.41	0.99

347	18	16	-67.54	1.00	-5.67	0.98
348	19	16	-46.35	1.00	-6.33	0.98
349	20	16	-68.34	1.00	-5.63	0.98
350	21	16	-86.97	1.00	-3.59	0.96
351	22	16	-79.04	1.00	-3.68	0.96
352	23	16	-91.05	1.00	-4.73	0.97
353	1	17	-74.45	1.00	-4.08	0.96
354	2	17	-3.78	0.96	-4.43	0.97
355	3	17	-40.30	1.00	-6.85	0.98
356	4	17	-85.42	1.00	-3.37	0.95
357	5	17	-52.21	1.00	-6.45	0.98
358	6	17	-74.03	1.00	-4.12	0.96
359	7	17	-17.73	1.00	-7.17	0.98
360	8	17	-45.34	1.00	-6.70	0.98
361	9	17	-59.87	1.00	-6.13	0.98
362	10	17	-59.03	1.00	-6.17	0.98
363	11	17	-58.03	1.00	-6.21	0.98
364	12	17	-64.75	1.00	-5.91	0.98
365	13	17	-78.88	1.00	-3.78	0.96
366	14	17	-89.06	1.00	-4.30	0.96
367	15	17	-14.81	1.00	-7.71	0.99
368	16	17	-40.36	1.00	-6.85	0.98
369	18	17	-70.28	1.00	-5.67	0.98
370	19	17	-55.25	1.00	-6.33	0.98
371	20	17	-70.95	1.00	-5.63	0.98
372	21	17	-87.67	1.00	-3.59	0.96
373	22	17	-80.32	1.00	-3.68	0.96
374	23	17	-91.55	1.00	-4.73	0.97
375	1	18	-49.96	1.00	-4.08	0.96
376	2	18	-73.57	1.00	-7.33	0.98
377	3	18	-70.22	1.00	-6.85	0.98
378	4	18	-77.83	1.00	-3.37	0.95
379	5	18	-65.76	1.00	-6.45	0.98
380	6	18	-47.88	1.00	-4.12	0.96
381	7	18	-73.05	1.00	-7.24	0.98
382	8	18	-68.80	1.00	-6.70	0.98
383	9	18	-59.26	1.00	-6.13	0.98
384	10	18	-60.25	1.00	-6.17	0.98
385	11	18	-61.32	1.00	-6.21	0.98
386	12	18	-50.34	1.00	-5.91	0.98
387	13	18	-64.62	1.00	-3.78	0.96
388	14	18	-83.56	1.00	-4.30	0.96
389	15	18	-64.46	1.00	-7.71	0.99
390	16	18	-70.21	1.00	-6.85	0.98
391	17	18	-74.03	1.00	-7.41	0.99
392	19	18	-63.75	1.00	-6.33	0.98
393	20	18	-16.78	1.00	-3.60	0.96
394	21	18	-81.46	1.00	-3.59	0.96
395	22	18	-68.05	1.00	-3.68	0.96
396	23	18	-87.13	1.00	-4.73	0.97
397	1	19	-68.74	1.00	-4.08	0.96

398	2	19	-56.42	1.00	-7.33	0.98
399	3	19	-47.68	1.00	-6.85	0.98
400	4	19	-83.07	1.00	-3.37	0.95
401	5	19	-25.40	1.00	-6.45	0.98
402	6	19	-68.11	1.00	-4.12	0.96
403	7	19	-55.24	1.00	-7.24	0.98
404	8	19	-42.72	1.00	-6.70	0.98
405	9	19	-36.27	1.00	-6.13	0.98
406	10	19	-32.40	1.00	-6.17	0.98
407	11	19	-26.57	1.00	-6.21	0.98
408	12	19	-51,28	1.00	-5.91	0.98
409	13	19	-74.88	1.00	-3.78	0.96
410	14	19	-87.32	1.00	-4.30	0.96
411	15	19	-49.39	1.00	-7.71	0.99
412	16	19	-47.62	1.00	-6.85	0.98
413	17	19	-57.42	1.00	-7.41	0.99
414	18	19	-62.16	1.00	-5.67	0.98
415	20	19	-63.29	1.00	-5.63	0.98
416	21	19	-85.72	1.00	-3.59	0.96
417	22	19	-76.77	1.00	-3.68	0.96
418	23	19	-90.15	1.00	-4.73	0.97
419	1	20	-47.28	1.00	-4.08	0.96
420	2	20	-74.34	1.00	-7.33	0.98
421	3	20	-71.11	1.00	-6.85	0.98
422	4	20	-77.37	1.00	-3.37	0.95
423	5	20	-66.86	1.00	-6.45	0.98
424	6	20	-44.82	1.00	-4.12	0.96
425	7	20	-73.83	1.00	-7.24	0.98
426	8	20	-69.75	1.00	-6.70	0.98
427	9	20	-60.78	1.00	-6.13	0.98
428	10	20	-61.70	1.00	-6.17	0.98
429	11	20	-62.69	1.00	-6.21	0.98
430	12	20	-52.76	1.00	-5.91	0.98
431	13	20	-63.55	1.00	-3.78	0.96
432	14	20	-83.24	1.00	-4.30	0.96
433	15	20	-65.18	1.00	-7.71	0.99
434	16	20	-71.10	1.00	-6.85	0.98
435	17	20	-74.79	1.00	-7.41	0.99
436	18	20	-16.87	1.00	-3.46	0.96
437	19	20	-64.96	1.00	-6.33	0.98
438	21	20	-81.09	1.00	-3.59	0.96
439	22	20	-67.19	1.00	-3.68	0.96
440	23	20	-86.87	1.00	-4.73	0.97
441	1	21	-73.02	1.00	-4.08	0.96
442	2	21	-85.98	1.00	-7.33	0.98
443	3	21	-84.43	1.00	-6.85	0.98
444	4	21	-46.92	1.00	-3.37	0.95
445	5	21	-82.74	1.00	-6.43	0.98
446	6	21	-73.42	1.00	-4.12	0.96
447	7	21	-85.72	1.00	-7.24	0.98
448	8	21	-83.85	1.00	-6.70	0.98

449	9	21	-80.87	1.00	-6.13	0.98
450	10	21	-81.12	1.00	-6.17	0.98
451	11	21	-81.40	1.00	-6.21	0.98
452	12	21	-79.11	1.00	-5.91	0.98
453	13	21	-67.72	1.00	-3.78	0.96
454	14	21	-40.18	1.00	-4.30	0.96
455	15	21	-87.02	1.00	-7.71	0.99
456	16	21	-84.42	1.00	-6.85	0.98
457	17	21	-86.22	1.00	-7.41	0.99
458	18	21	-76.25	1.00	-5.67	0.98
459	19	21	-82.09	1.00	-6.33	0.98
460	20	21	-75.80	1.00	-5.63	0.98
461	22	21	-65.18	1.00	-3.68	0.96
462	23	21	-59.14	1.00	-4.73	0.97
463	1	22	-59.98	1.00	-4.08	0.96
464	2	22	-83.31	1.00	-7.33	0.98
465	3	22	-81.25	1.00	-6.85	0.98
466	4	22	-62.47	1.00	-3.37	0.95
467	5	22	-78.86	1.00	-6.45	0.98
468	6	22	-61.03	1.00	-4.12	0.96
469	7	22	-82.98	1.00	-7.24	0.98
470	8	22	-80.45	1.00	-6.70	0.98
471	9	22	-75.97	1.00	-6.13	0.98
472	10	22	-76.37	1.00	-6.17	0.98
473	11	22	-76.82	1.00	-6.21	0.98
474	12	22	-73.03	1.00	-5.91	0.98
475	13	22	-37.74	1.00	-3.78	0.96
476	14	22	-73.62	1.00	-4.30	0.96
477	15	22	-84.63	1.00	-7.71	0.99
478	16	22	-81.25	1.00	-6.85	0.98
479	17	22	-83.61	1.00	-7.41	0.99
480	18	22	-67.59	1.00	-5.67	0.98
481	19	22	-77.89	1.00	-6.33	0.98
482	20	22	-66.64	1.00	-5.63	0.98
483	21	22	-69.92	1.00	-3.59	0.96
484	23	22	-79.24	1.00	-4.73	0.97
485	1	23	-88.75	1.00	-4.08	0.96
486	2	23	-99.05	1.00	-7.33	0.98
487	3	23	-97.69	1.00	-6.85	0.98
488	4	23	-75.29	1.00	-3.37	0.95
489	5	23	-96.25	1.00	-6.45	0.98
490	6	23	-89.03	1.00	-4.12	0.96
491	7	23	-98.83	1.00	-7.24	0.98
492	8	23	-97.19	1.00	-6.70	0.98
493	9	23	-94.69	1.00	-6.13	0.98
494	10	23	-94.90	1.00	-6.17	0.98
495	11	23	-95.13	1.00	-6.21	0.98
496	12	23	-93.28	1.00	-5.91	0.98
497	13	23	-85.22	1.00	-3.78	0.95
498	14	23	-61.25	1.00	-4.30	0.96
499	15	23	-99.99	1.00	-7.71	0.99

500	16	23	-97.69	1.00	-6.85	0.98
501	17	23	-99.27	1.00	-7.41	0.99
502	18	23	-91.09	1.00	-5.67	0.98
503	19	23	-95.70	1.00	-6.33	0.98
504	20	23	-90.75	1.00	-5.63	0.98
505	21	23	-68.31	1.00	-3.59	0.96
506	22	23	-83.67	1.00	-3.68	0.96

RF COUPLING PATHS WITH INTERFERENCE LEVELS
(MODIFIED FREQUENCY SET)

Path	Rcvr No.	Xmtr No.	RAS EIL (dB)	RAS IPS	TAS EIL (dB)	TAS IPS
001	2	1	-76.90	1.00	-6.92	0.98
002	3	1	-74.21	1.00	-6.24	0.98
003	4	1	-72.90	1.00	-3.37	0.95
004	5	1	-70.84	1.00	-5.66	0.98
005	6	1	-11.28	0.99	1.26	0.87
006	7	1	-76.47	1.00	-6.80	0.98
007	8	1	-73.11	1.00	-6.03	0.98
008	9	1	-66.40	1.00	-5.16	0.97
009	10	1	-67.04	1.00	-5.22	0.97
010	11	1	-67.75	1.00	-5.29	0.97
011	12	1	-61.28	1.00	-4.81	0.97
012	13	1	-53.90	1.00	-3.78	0.96
013	14	1	-79.78	1.00	-4.30	0.96
014	15	1	-67.48	1.00	-7.45	0.99
015	16	1	-76.08	1.00	-6.69	0.98
016	17	1	-77.29	1.00	-7.04	0.98
017	18	1	-49.04	1.00	-4.40	0.97
018	19	1	-69.40	1.00	-5.47	0.97
019	20	1	-46.27	1.00	-4.34	0.96
020	21	1	-77.31	1.00	-3.59	0.96
021	22	1	-59.52	1.00	-3.68	0.96
022	23	1	-83.86	1.00	-4.73	0.97
023	1	2	-74.23	1.00	-4.08	0.96
024	3	2	-38.09	1.00	-6.85	0.98
025	4	2	-85.33	1.00	-3.37	0.95
026	5	2	-51.19	1.00	-6.45	0.98
027	6	2	-73.80	1.00	-4.12	0.96
028	7	2	-6.96	0.97	-5.26	0.97
029	8	2	-43.74	1.00	-6.70	0.98
030	9	2	-59.25	1.00	-6.13	0.98
031	10	2	-58.38	1.00	-6.17	0.98
032	11	2	-57.34	1.00	-6.21	0.98
033	12	2	-64.31	1.00	-5.91	0.98
034	13	2	-78.72	1.00	-3.78	0.96
035	14	2	-88.99	1.00	-4.30	0.96

036	15	2	-19.41	1.00	-7.71	0.99
037	16	2	-18.11	1.00	-7.12	0.98
038	17	2	-3.87	0.96	-4.51	0.97
039	18	2	-69.98	1.00	-5.67	0.98
040	19	2	-54.42	1.00	-6.33	0.98
041	20	2	-70.66	1.00	-5.63	0.98
042	21	2	-87.59	1.00	-3.59	0.96
043	22	2	-80.18	1.00	-3.68	0.96
044	23	2	-91.50	1.00	-4.73	0.97
045	1	3	-72.46	1.00	-4.08	0.96
046	2	3	-39.01	1.00	-7.33	0.98
047	4	3	-84.57	1.00	-3.37	0.95
048	5	3	-40.96	1.00	-6.45	0.98
049	6	3	-71.97	1.00	-4.12	0.96
050	7	3	-35.86	1.00	-7.24	0.98
051	8	3	-22.42	1.00	-6.70	0.98
052	9	3	-53.88	1.00	-6.13	0.98
053	10	3	-52.65	1.00	-6.17	0.98
054	11	3	-51.12	1.00	-6.21	0.98
055	12	3	-60.64	1.00	-5.91	0.98
056	13	3	-77.45	1.00	-3.78	0.96
057	14	3	-88.44	1.00	-4.30	0.96
058	15	3	-36.62	1.00	-7.71	0.99
059	16	3	-32.43	1.00	-7.17	0.98
060	17	3	-41.39	1.00	-7.41	0.99
061	18	3	-67.55	1.00	-5.67	0.98
062	19	3	-46.59	1.00	-6.33	0.98
063	20	3	-68.35	1.00	-5.63	0.98
064	21	3	-86.97	1.00	-3.59	0.96
065	22	3	-79.05	1.00	-3.68	0.96
066	23	3	-91.05	1.00	-4.73	0.97
067	1	4	-78.11	1.00	-4.08	0.96
068	2	4	-93.21	1.00	-6.92	0.98
069	3	4	-91.53	1.00	-6.24	0.98
070	5	4	-89.67	1.00	-5.66	0.98
071	6	4	-78.61	1.00	-4.12	0.96
072	7	4	-92.93	1.00	-6.80	0.98
073	8	4	-90.90	1.00	-6.03	0.98
074	9	4	-87.55	1.00	-5.16	0.97
075	10	4	-87.83	1.00	-5.22	0.97
076	11	4	-88.16	1.00	-5.29	0.97
077	12	4	-85.52	1.00	-4.81	0.97
078	13	4	-70.97	1.00	-3.78	0.96
079	14	4	-65.39	1.00	-4.30	0.96
080	15	4	-94.32	1.00	-7.45	0.99
081	16	4	-92.68	1.00	-6.69	0.98
082	17	4	-93.47	1.00	-7.04	0.98
083	18	4	-82.12	1.00	-4.40	0.97
084	19	4	-88.94	1.00	-5.47	0.97
085	20	4	-81.57	1.00	-4.34	0.96
086	21	4	-56.42	1.00	-3.59	0.96

087	22	4	-67.23	1.00	-3.68	0.96
088	23	4	-75.61	1.00	-4.73	0.97
089	1	5	-69.91	1.00	-4.08	0.96
090	2	5	-52.92	1.00	-7.33	0.98
091	3	5	-41.77	1.00	-6.85	0.98
092	4	5	-83.52	1.00	-3.37	0.95
093	6	5	-69.32	1.00	-4.12	0.96
094	7	5	-51.50	1.00	-7.24	0.98
095	8	5	-34.48	1.00	-6.70	0.98
096	9	5	-43.42	1.00	-6.13	0.98
097	10	5	-41.00	1.00	-6.17	0.98
098	11	5	-37.74	1.00	-6.21	0.98
099	12	5	-54.55	1.00	-5.91	0.98
100	13	5	-75.67	1.00	-3.78	0.96
101	14	5	-87.66	1.00	-4.30	0.96
102	15	5	-46.57	1.00	-7.71	0.99
103	16	5	-50.10	1.00	-7.17	0.98
104	17	5	-54.10	1.00	-7.41	0.99
105	18	5	-63.91	1.00	-5.67	0.98
106	19	5	-25.13	1.00	-6.33	0.98
107	20	5	-64.92	1.00	-5.63	0.98
108	21	5	-86.10	1.00	-3.59	0.96
109	22	5	-77.47	1.00	-3.68	0.96
110	23	5	-90.43	1.00	-4.73	0.97
111	1	6	-11.24	0.99	1.10	0.87
112	2	6	-76.43	1.00	-6.92	0.98
113	3	6	-73.68	1.00	-6.24	0.98
114	4	6	-73.36	1.00	-3.37	0.95
115	5	6	-70.22	1.00	-5.66	0.98
116	7	6	-76.00	1.00	-6.80	0.98
117	8	6	-72.55	1.00	-6.03	0.98
118	9	6	-65.61	1.00	-5.16	0.97
119	10	6	-66.28	1.00	-5.22	0.97
120	11	6	-67.02	1.00	-5.29	0.97
121	12	6	-60.24	1.00	-4.81	0.97
122	13	6	-55.29	1.00	-3.78	0.96
123	14	6	-80.09	1.00	-4.30	0.96
124	15	6	-67.04	1.00	-7.45	0.99
125	16	6	-75.59	1.00	-6.69	0.98
126	17	6	-76.82	1.00	-7.04	0.98
127	18	6	-46.92	1.00	-4.40	0.97
128	19	6	-68.73	1.00	-5.47	0.97
129	20	6	-43.77	1.00	-4.34	0.96
130	21	6	-77.67	1.00	-3.59	0.96
131	22	6	-60.53	1.00	-3.68	0.96
132	23	6	-84.11	1.00	-4.73	0.97
133	1	7	-73.96	1.00	-4.08	0.96
134	2	7	-7.12	0.98	-5.35	0.97
135	3	7	-35.10	1.00	-6.85	0.98
136	4	7	-85.21	1.00	-3.37	0.95
137	5	7	-49.92	1.00	-6.45	0.98

138	6	7	-73.52	1.00	-4.12	0.96
139	8	7	-41.69	1.00	-6.70	0.98
140	9	7	-58.51	1.00	-6.13	0.98
141	10	7	-57.60	1.00	-6.17	0.98
142	11	7	-56.49	1.00	-6.21	0.98
143	12	7	-63.78	1.00	-5.91	0.98
144	13	7	-78.53	1.00	-3.78	0.96
145	14	7	-88.91	1.00	-4.30	0.96
146	15	7	-23.55	1.00	-7.71	0.99
147	16	7	-5.38	0.97	-4.65	0.97
148	17	7	-18.05	1.00	-7.34	0.98
149	18	7	-69.62	1.00	-5.67	0.98
150	19	7	-53.39	1.00	-6.33	0.98
151	20	7	-70.32	1.00	-5.63	0.98
152	21	7	-87.50	1.00	-3.59	0.96
153	22	7	-80.01	1.00	-3.68	0.96
154	23	7	-91.43	1.00	-4.73	0.97
155	1	8	-71.66	1.00	-4.08	0.96
156	2	8	-44.97	1.00	-7.33	0.98
157	3	8	-22.72	1.00	-6.85	0.98
158	4	8	-84.24	1.00	-3.37	0.95
159	5	8	-33.97	1.00	-6.45	0.98
160	6	8	-71.14	1.00	-4.12	0.96
161	7	8	-42.75	1.00	-7.24	0.98
162	9	8	-51.06	1.00	-6.13	0.98
163	10	8	-49.58	1.00	-6.17	0.98
164	11	8	-47.71	1.00	-6.21	0.98
165	12	8	-58.85	1.00	-5.91	0.98
166	13	8	-76.88	1.00	-3.78	0.96
167	14	8	-88.19	1.00	-4.30	0.96
168	15	8	-40.60	1.00	-7.71	0.99
169	16	8	-40.46	1.00	-7.17	0.98
170	17	8	-46.72	1.00	-7.41	0.99
171	18	8	-66.43	1.00	-5.67	0.98
172	19	8	-41.93	1.00	-6.33	0.98
173	20	8	-67.29	1.00	-5.63	0.98
174	21	8	-86.69	1.00	-3.59	0.96
175	22	8	-78.54	1.00	-3.68	0.96
176	23	8	-90.85	1.00	-4.73	0.97
177	1	9	-66.18	1.00	-4.08	0.96
178	2	9	-61.70	1.00	-7.33	0.98
179	3	9	-55.41	1.00	-6.85	0.98
180	4	9	-82.12	1.00	-3.37	0.95
181	5	9	-44.14	1.00	-6.45	0.98
182	6	9	-65.43	1.00	-4.12	0.96
183	7	9	-60.80	1.00	-7.24	0.98
184	8	9	-52.29	1.00	-6.70	0.98
185	10	9	-8.86	0.98	-3.56	0.96
186	11	9	-22.06	1.00	-6.18	0.98
187	12	9	-42.22	1.00	-5.91	0.98
188	13	9	-73.20	1.00	-3.78	0.96

189	14	9	-86.62	1.00	-4.30	0.96
190	15	9	-53.83	1.00	-7.71	0.99
191	16	9	-59.94	1.00	-7.17	0.98
192	17	9	-62.48	1.00	-7.41	0.99
193	18	9	-58.11	1.00	-5.67	0.98
194	19	9	-36.71	1.00	-6.33	0.98
195	20	9	-59.55	1.00	-5.63	0.98
196	21	9	-84.93	1.00	-3.59	0.96
197	22	9	-75.29	1.00	-3.68	0.96
198	23	9	-89.58	1.00	-4.73	0.97
199	1	10	-66.73	1.00	-4.08	0.96
200	2	10	-60.75	1.00	-7.33	0.98
201	3	10	-54.09	1.00	-6.85	0.98
202	4	10	-82.32	1.00	-3.37	0.95
203	5	10	-41.63	1.00	-6.45	0.98
204	6	10	-66.01	1.00	-4.12	0.96
205	7	10	-59.80	1.00	-7.24	0.98
206	8	10	-50.72	1.00	-6.70	0.98
207	9	10	-8.78	0.98	-3.70	0.96
208	11	10	-11.09	0.99	-4.51	0.97
209	12	10	-44.50	1.00	-5.91	0.98
210	13	10	-73.56	1.00	-3.78	0.96
211	14	10	-86.77	1.00	-4.30	0.96
212	15	10	-53.02	1.00	-7.71	0.99
213	16	10	-58.89	1.00	-7.17	0.98
214	17	10	-61.56	1.00	-7.41	0.99
215	18	10	-59.02	1.00	-5.67	0.98
216	19	10	-32.76	1.00	-6.33	0.98
217	20	10	-60.38	1.00	-5.63	0.98
218	21	10	-85.10	1.00	-3.59	0.96
219	22	10	-75.61	1.00	-3.68	0.96
220	23	10	-89.70	1.00	-4.73	0.97
221	1	11	-67.34	1.00	-4.08	0.96
222	2	11	-59.60	1.00	-7.33	0.98
223	3	11	-52.46	1.00	-6.85	0.98
224	4	11	-82.54	1.00	-3.37	0.95
225	5	11	-38.26	1.00	-6.45	0.98
226	6	11	-66.65	1.00	-4.12	0.96
227	7	11	-58.60	1.00	-7.24	0.98
228	8	11	-48.75	1.00	-6.70	0.98
229	9	11	-21.87	1.00	-6.13	0.98
230	10	11	-10.99	0.99	-4.63	0.97
231	12	11	-46.75	1.00	-5.91	0.98
232	13	11	-73.95	1.00	-3.78	0.96
233	14	11	-86.93	1.00	-4.30	0.96
234	15	11	-52.04	1.00	-7.71	0.99
235	16	11	-57.63	1.00	-7.17	0.98
236	17	11	-60.46	1.00	-7.41	0.99
237	18	11	-59.99	1.00	-5.67	0.98
238	19	11	-26.83	1.00	-6.33	0.98
239	20	11	-61.28	1.00	-5.63	0.98

240	21	11	-85.28	1.00	-3.59	0.96
241	22	11	-75.95	1.00	-3.68	0.96
242	23	11	-89.84	1.00	-4.73	0.97
243	1	12	-61.58	1.00	-4.08	0.96
244	2	12	-67.28	1.00	-7.33	0.98
245	3	12	-62.68	1.00	-6.85	0.98
246	4	12	-80.61	1.00	-3.37	0.95
247	5	12	-55.78	1.00	-6.45	0.98
248	6	12	-60.58	1.00	-4.12	0.96
249	7	12	-66.59	1.00	-7.24	0.98
250	8	12	-60.59	1.00	-6.70	0.98
251	9	12	-42.74	1.00	-6.13	0.98
252	10	12	-45.10	1.00	-6.17	0.98
253	11	12	-47.46	1.00	-6.21	0.98
254	13	12	-80.39	1.00	-3.78	0.96
255	14	12	-85.52	1.00	-4.30	0.96
256	15	12	-58.74	1.00	-7.71	0.99
257	16	12	-65.94	1.00	-7.17	0.98
258	17	12	-67.88	1.00	-7.41	0.99
259	18	12	-49.72	1.00	-5.67	0.98
260	19	12	-52.24	1.00	-6.33	0.98
261	20	12	-52.05	1.00	-5.63	0.98
262	21	12	-83.69	1.00	-3.59	0.96
263	22	12	-72.87	1.00	-3.68	0.96
264	23	12	-88.70	1.00	-4.73	0.97
265	1	13	-58.64	1.00	-4.08	0.96
266	2	13	-86.13	1.00	-6.92	0.98
267	3	13	-83.94	1.00	-6.24	0.98
268	4	13	-70.50	1.00	-3.37	0.95
269	5	13	-81.35	1.00	-5.66	0.98
270	6	13	-60.07	1.00	-4.12	0.96
271	7	13	-85.78	1.00	-6.80	0.98
272	8	13	-83.07	1.00	-6.03	0.98
273	9	13	-78.16	1.00	-5.16	0.97
274	10	13	-78.61	1.00	-5.22	0.97
275	11	13	-79.10	1.00	-5.29	0.97
276	12	13	-74.84	1.00	-4.81	0.97
277	14	13	-79.99	1.00	-4.30	0.96
278	15	13	-87.52	1.00	-7.45	0.99
279	16	13	-85.45	1.00	-6.69	0.98
280	17	13	-86.45	1.00	-7.04	0.98
281	18	13	-68.43	1.00	-4.40	0.97
282	19	13	-80.28	1.00	-5.47	0.97
283	20	13	-67.28	1.00	-4.34	0.96
284	21	13	-76.75	1.00	-3.59	0.96
285	22	13	-42.02	1.00	-3.68	0.96
286	23	13	-85.08	1.00	-4.73	0.97
287	1	14	-76.37	1.00	-4.08	0.96
288	2	14	-88.25	1.00	-6.92	0.98
289	3	14	-86.77	1.00	-6.24	0.98
290	4	14	-56.77	1.00	-3.37	0.95

291	5	14	-85.18	1.00	-5.66	0.98
292	6	14	-76.72	1.00	-4.12	0.96
293	7	14	-88.01	1.00	-6.80	0.98
294	8	14	-86.23	1.00	-6.03	0.98
295	9	14	-83.43	1.00	-5.16	0.97
296	10	14	-83.66	1.00	-5.22	0.97
297	11	14	-83.93	1.00	-5.29	0.97
298	12	14	-81.81	1.00	-4.81	0.97
299	13	14	-71.84	1.00	-3.78	0.96
300	15	14	-89.25	1.00	-7.45	0.99
301	16	14	-87.78	1.00	-6.69	0.98
302	17	14	-88.48	1.00	-7.04	0.98
303	18	14	-79.23	1.00	-4.40	0.97
304	19	14	-84.58	1.00	-5.47	0.97
305	20	14	-78.82	1.00	-4.34	0.96
306	21	14	-41.06	1.00	-3.59	0.96
307	22	14	-69.75	1.00	-3.68	0.96
308	23	14	-52.95	1.00	-4.73	0.97
309	1	15	-77.85	1.00	-4.08	0.96
310	2	15	-32.46	1.00	-7.33	0.98
311	3	15	-48.75	1.00	-6.85	0.98
312	4	15	-88.42	1.00	-3.37	0.95
313	5	15	-57.88	1.00	-6.45	0.98
314	6	15	-77.45	1.00	-4.12	0.96
315	7	15	-36.44	1.00	-7.24	0.98
316	8	15	-52.43	1.00	-6.70	0.98
317	9	15	-64.43	1.00	-6.13	0.98
318	10	15	-63.70	1.00	-6.17	0.98
319	11	15	-62.83	1.00	-6.21	0.98
320	12	15	-68.82	1.00	-5.91	0.98
321	13	15	-82.08	1.00	-3.78	0.96
322	14	15	-91.97	1.00	-4.30	0.96
323	16	15	-39.39	1.00	-7.17	0.98
324	17	15	-28.02	1.00	-7.41	0.99
325	18	15	-73.92	1.00	-5.67	0.98
326	19	15	-60.43	1.00	-6.33	0.98
327	20	15	-74.54	1.00	-5.63	0.98
328	21	15	-90.61	1.00	-3.59	0.96
329	22	15	-83.47	1.00	-3.68	0.96
330	23	15	-94.41	1.00	-4.73	0.97
331	1	16	-73.72	1.00	-4.08	0.96
332	2	16	-18.42	1.00	-7.28	0.98
333	3	16	-31.81	1.00	-6.85	0.98
334	4	16	-85.11	1.00	-3.37	0.95
335	5	16	-48.67	1.00	-6.45	0.98
336	6	16	-73.27	1.00	-4.12	0.96
337	7	16	-5.53	0.97	-4.73	0.97
338	8	16	-39.55	1.00	-6.70	0.98
339	9	16	-57.79	1.00	-6.13	0.98
340	10	16	-56.84	1.00	-6.17	0.98
341	11	16	-55.68	1.00	-6.21	0.98

342	12	16	-63.28	1.00	-5.91	0.98
343	13	16	-78.35	1.00	-3.78	0.96
344	14	16	-88.83	1.00	-4.30	0.96
345	15	16	-26.65	1.00	-7.71	0.99
346	17	16	-25.00	1.00	-7.41	0.99
347	18	16	-69.28	1.00	-5.67	0.98
348	19	16	-52.39	1.00	-6.33	0.98
349	20	16	-69.99	1.00	-5.63	0.98
350	21	16	-87.41	1.00	-3.59	0.96
351	22	16	-79.85	1.00	-3.68	0.96
352	23	16	-91.37	1.00	-4.73	0.97
353	1	17	-74.45	1.00	-4.08	0.96
354	2	17	-3.78	0.96	-4.43	0.97
355	3	17	-40.30	1.00	-6.85	0.98
356	4	17	-85.42	1.00	-3.37	0.95
357	5	17	-52.21	1.00	-6.45	0.98
358	6	17	-74.03	1.00	-4.12	0.96
359	7	17	-17.73	1.00	-7.17	0.98
360	8	17	-45.34	1.00	-6.70	0.98
361	9	17	-59.87	1.00	-6.13	0.98
362	10	17	-59.03	1.00	-6.17	0.98
363	11	17	-58.03	1.00	-6.21	0.98
364	12	17	-64.75	1.00	-5.91	0.98
365	13	17	-78.88	1.00	-3.78	0.96
366	14	17	-89.06	1.00	-4.30	0.96
367	15	17	-14.81	1.00	-7.71	0.99
368	16	17	-24.54	1.00	-7.17	0.98
369	18	17	-70.28	1.00	-5.67	0.98
370	19	17	-55.25	1.00	-6.33	0.98
371	20	17	-70.95	1.00	-5.63	0.98
372	21	17	-87.67	1.00	-3.59	0.96
373	22	17	-80.32	1.00	-3.68	0.96
374	23	17	-91.55	1.00	-4.73	0.97
375	1	18	-49.96	1.00	-4.08	0.96
376	2	18	-73.57	1.00	-7.33	0.98
377	3	18	-70.22	1.00	-6.85	0.98
378	4	18	-77.83	1.00	-3.37	0.95
379	5	18	-65.76	1.00	-6.45	0.98
380	6	18	-47.88	1.00	-4.12	0.96
381	7	18	-73.05	1.00	-7.24	0.98
382	8	18	-68.80	1.00	-6.70	0.98
383	9	18	-59.26	1.00	-6.13	0.98
384	10	18	-60.25	1.00	-6.17	0.98
385	11	18	-61.32	1.00	-6.21	0.98
386	12	18	-50.34	1.00	-5.91	0.98
387	13	18	-64.62	1.00	-3.78	0.96
388	14	18	-83.56	1.00	-4.30	0.96
389	15	18	-64.46	1.00	-7.71	0.99
390	16	18	-72.56	1.00	-7.17	0.98
391	17	18	-74.03	1.00	-7.41	0.99
392	19	18	-63.75	1.00	-6.33	0.98

393	20	18	-16.78	1.00	-3.60	0.96
394	21	18	-81.46	1.00	-3.59	0.96
395	22	18	-68.05	1.00	-3.68	0.96
396	23	18	-87.13	1.00	-4.73	0.97
397	1	19	-68.74	1.00	-4.08	0.96
398	2	19	-56.42	1.00	-7.33	0.98
399	3	19	-47.68	1.00	-6.85	0.98
400	4	19	-83.07	1.00	-3.37	0.95
401	5	19	-25.40	1.00	-6.45	0.98
402	6	19	-68.11	1.00	-4.12	0.96
403	7	19	-55.24	1.00	-7.24	0.98
404	8	19	-42.72	1.00	-6.70	0.98
405	9	19	-36.27	1.00	-6.13	0.98
406	10	19	-32.40	1.00	-6.17	0.98
407	11	19	-26.57	1.00	-6.21	0.98
408	12	19	-51,28	1.00	-5.91	0.98
409	13	19	-74.88	1.00	-3.78	0.96
410	14	19	-87.32	1.00	-4.30	0.96
411	15	19	-49.39	1.00	-7.71	0.99
412	16	19	-54.09	1.00	-7.17	0.98
413	17	19	-57.42	1.00	-7.41	0.99
414	18	19	-62.16	1.00	-5.67	0.98
415	20	19	-63.29	1.00	-5.63	0.98
416	21	19	-85.72	1.00	-3.59	0.96
417	22	19	-76.77	1.00	-3.68	0.96
418	23	19	-90.15	1.00	-4.73	0.97
419	1	20	-47.28	1.00	-4.08	0.96
420	2	20	-74.34	1.00	-7.33	0.98
421	3	20	-71.11	1.00	-6.85	0.98
422	4	20	-77.37	1.00	-3.37	0.95
423	5	20	-66.86	1.00	-6.45	0.98
424	6	20	-44.82	1.00	-4.12	0.96
425	7	20	-73.83	1.00	-7.24	0.98
426	8	20	-69.75	1.00	-6.70	0.98
427	9	20	-60.78	1.00	-6.13	0.98
428	10	20	-61.70	1.00	-6.17	0.98
429	11	20	-62.69	1.00	-6.21	0.98
430	12	20	-52.76	1.00	-5.91	0.98
431	13	20	-63.55	1.00	-3.78	0.96
432	14	20	-83.24	1.00	-4.30	0.96
433	15	20	-65.18	1.00	-7.71	0.99
434	16	20	-73.37	1.00	-7.17	0.98
435	17	20	-74.79	1.00	-7.41	0.99
436	18	20	-16.87	1.00	-3.46	0.96
437	19	20	-64.96	1.00	-6.33	0.98
438	21	20	-81.09	1.00	-3.59	0.96
439	22	20	-67.19	1.00	-3.68	0.96
440	23	20	-86.87	1.00	-4.73	0.97
441	1	21	-73.02	1.00	-4.08	0.96
442	2	21	-85.98	1.00	-6.92	0.98
443	3	21	-84.43	1.00	-6.24	0.98

444	4	21	-46.92	1.00	-3.37	0.95
445	5	21	-82.74	1.00	-5.66	0.98
446	6	21	-73.42	1.00	-4.12	0.96
447	7	21	-85.72	1.00	-6.80	0.98
448	8	21	-83.85	1.00	-6.03	0.98
449	9	21	-80.87	1.00	-5.16	0.97
450	10	21	-81.12	1.00	-5.22	0.97
451	11	21	-81.40	1.00	-5.29	0.97
452	12	21	-79.11	1.00	-4.81	0.97
453	13	21	-67.72	1.00	-3.78	0.96
454	14	21	-40.18	1.00	-4.30	0.96
455	15	21	-87.02	1.00	-7.45	0.99
456	16	21	-85.49	1.00	-6.69	0.98
457	17	21	-86.22	1.00	-7.04	0.98
458	18	21	-76.25	1.00	-4.40	0.97
459	19	21	-82.09	1.00	-5.47	0.97
460	20	21	-75.80	1.00	-4.34	0.96
461	22	21	-65.18	1.00	-3.68	0.96
462	23	21	-59.14	1.00	-4.73	0.97
463	1	22	-59.98	1.00	-4.08	0.96
464	2	22	-83.31	1.00	-6.92	0.98
465	3	22	-81.25	1.00	-6.24	0.98
466	4	22	-62.47	1.00	-3.37	0.95
467	5	22	-78.86	1.00	-5.66	0.98
468	6	22	-61.03	1.00	-4.12	0.96
469	7	22	-82.98	1.00	-6.80	0.98
470	8	22	-80.45	1.00	-6.03	0.98
471	9	22	-75.97	1.00	-5.16	0.97
472	10	22	-76.37	1.00	-5.22	0.97
473	11	22	-76.82	1.00	-5.29	0.97
474	12	22	-73.03	1.00	-4.81	0.97
475	13	22	-37.74	1.00	-3.78	0.96
476	14	22	-73.62	1.00	-4.30	0.96
477	15	22	-84.63	1.00	-7.45	0.99
478	16	22	-82.67	1.00	-6.69	0.98
479	17	22	-83.61	1.00	-7.04	0.98
480	18	22	-67.59	1.00	-4.40	0.97
481	19	22	-77.89	1.00	-5.47	0.97
482	20	22	-66.64	1.00	-4.34	0.96
483	21	22	-69.92	1.00	-3.59	0.96
484	23	22	-79.24	1.00	-4.73	0.97
485	1	23	-88.75	1.00	-4.08	0.96
486	2	23	-99.05	1.00	-6.92	0.98
487	3	23	-97.69	1.00	-6.24	0.98
488	4	23	-75.29	1.00	-3.37	0.95
489	5	23	-96.25	1.00	-5.66	0.98
490	6	23	-89.03	1.00	-4.12	0.96
491	7	23	-98.83	1.00	-6.80	0.98
492	8	23	-97.19	1.00	-6.03	0.98
493	9	23	-94.69	1.00	-5.16	0.97
494	10	23	-94.90	1.00	-5.22	0.97

495	11	23	-95.13	1.00	-5.29	0.97
496	12	23	-93.28	1.00	-4.81	0.97
497	13	23	-85.22	1.00	-3.78	0.95
498	14	23	-61.25	1.00	-4.30	0.96
499	15	23	-99.99	1.00	-7.45	0.99
500	16	23	-98.62	1.00	-6.69	0.98
501	17	23	-99.27	1.00	-7.04	0.98
502	18	23	-91.09	1.00	-4.40	0.97
503	19	23	-95.70	1.00	-5.47	0.97
504	20	23	-90.75	1.00	-4.34	0.96
505	21	23	-68.31	1.00	-3.59	0.96
506	22	23	-83.67	1.00	-3.68	0.96

APPENDIX B

RECEIVER PERFORMANCE REPORTS
(SPS MODE)

RECEIVER #1

Frequency:	9.397 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-128.38 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-108.64 dBm
Total Undesired Power:	-123.22 dBm
SPS:	0.84

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.013	3.69	0.821	0.002	13 14 21
TAS	0.100	-0.98	0.919	0.008	6
FTIM	0.050	-1.12	0.920	0.004	15 18
FTIM	0.002	-1.34	0.922	0.000	6 9 14 21 23
TAS	1.000	-4.38	0.965	0.035	14
TAS	1.000	-4.38	0.965	0.035	23
TAS	0.058	-4.38	0.965	0.002	4
TAS	0.500	-4.38	0.965	0.017	21
TAS	0.042	-4.38	0.965	0.001	10
TAS	0.067	-4.38	0.965	0.002	20
TAS	0.050	-4.38	0.965	0.002	12
TAS	0.050	-4.38	0.965	0.002	18
TAS	0.033	-4.38	0.965	0.001	11
TAS	1.000	-4.47	0.966	0.034	15
TAS	0.025	-4.47	0.966	0.001	13
TAS	0.033	-4.47	0.966	0.001	19
TAS	0.042	-4.47	0.966	0.001	9
TAS	0.025	-4.47	0.966	0.001	22
TAS	0.025	-4.47	0.966	0.001	7

POWER REDUCTION TABLE - RX #1

TX	CHANGE IN SPS
2	0.000
3	0.000
4	0.000
5	0.000
6	0.002
7	0.000
8	0.000
9	0.001
10	0.000
11	0.000
12	0.000
13	0.001
14	0.010
15	0.009
16	0.000
17	0.000
18	0.001
19	0.000
20	0.001
21	0.005
22	0.001
23	0.009

RECEIVER #2

Frequency:	2.514 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-124.09 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-105.76 dBm
Total Undesired Power:	-121.15 dBm
SPS:	0.85

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.025	18.56	0.295	0.018	22 23
FTIM	0.50	-5.10	0.963	0.002	6 14 15 21
TAS	0.025	-7.01	0.984	0.000	7
FTIM	0.003	-8.02	0.984	0.000	4 6 14 21 22
TAS	1.000	-7.14	0.984	0.016	14
TAS	1.000	-7.14	0.984	0.016	23
TAS	0.058	-7.14	0.984	0.001	4
TAS	0.100	-7.14	0.984	0.002	6
TAS	0.500	-7.14	0.984	0.008	21
TAS	0.025	-7.22	0.985	0.000	13
TAS	0.025	-7.22	0.985	0.000	22
TAS	0.042	-7.55	0.986	0.001	10
TAS	0.067	-7.55	0.986	0.001	20
TAS	0.050	-7.55	0.986	0.001	12
TAS	0.050	-7.55	0.986	0.001	18
TAS	0.033	-7.55	0.986	0.000	11
TAS	1.000	-7.63	0.987	0.013	15
TAS	0.033	-7.63	0.987	0.000	19
TAS	0.042	-7.63	0.987	0.001	9
TAS	0.025	-7.63	0.987	0.000	8

POWER REDUCTION TABLE - RX #2

TX	CHANGE IN SPS
1	0.000
3	0.000
4	0.000
5	0.000
6	0.001
7	0.000
8	0.000
9	0.000
10	0.000
11	0.000
12	0.000
13	0.000
14	0.004
15	0.004
16	0.000
17	0.000
18	0.000
19	0.000
20	0.000
21	0.003
22	0.010
23	0.009

RECEIVER #3

Frequency:	3.263 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-124.94 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-106.45 dBm
Total Undesired Power:	-121.62 dBm
SPS:	0.87

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.001	14.29	0.408	0.001	12 14 18 21
FTIM	0.021	-1.45	0.923	0.002	10 15 21 23
FTIM	0.025	-2.82	0.943	0.001	14 15 22
FTIM	0.002	-3.43	0.950	0.000	6 9 14 21 23
TAS	1.000	-6.47	0.981	0.019	14
TAS	1.000	-6.47	0.981	0.019	23
TAS	0.058	-6.47	0.981	0.001	4
TAS	0.100	-6.47	0.981	0.002	6
TAS	0.500	-6.47	0.981	0.010	21
TAS	0.025	-6.56	0.981	0.000	13
TAS	0.025	-6.56	0.981	0.000	22
TAS	0.042	-7.08	0.984	0.001	10
TAS	0.067	-7.08	0.984	0.001	20
TAS	0.050	-7.08	0.984	0.001	12
TAS	0.050	-7.08	0.984	0.001	18
TAS	0.033	-7.08	0.984	0.001	11
TAS	1.000	-7.17	0.985	0.015	15
TAS	0.033	-7.17	0.985	0.001	19
TAS	0.042	-7.17	0.985	0.001	9
TAS	0.025	-7.17	0.985	0.000	7

POWER REDUCTION TABLE - RX #3

TX	CHANGE IN SPS
1	0.000
2	0.000
4	0.000
5	0.000
6	0.001
7	0.000
8	0.000
9	0.000
10	0.001
11	0.000
12	0.002
13	0.000
14	0.007
15	0.006
16	0.000
17	0.000
18	0.001
19	0.000
20	0.000
21	0.004
22	0.002
23	0.006

RECEIVER #4

Frequency:	16.167 MHz
Modulation Type:	Unsecure Voice
Mean Ambient Noise:	-130.15 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	8.00
Mean Desired Signal:	-108.40 dBm
Total Undesired Power:	-123.85 dBm
SPS:	0.84

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.001	5.06	0.784	0.000	12 15 18 21 23
FTIM	0.016	4.39	0.804	0.003	11 14 21
FTIM	0.001	-0.93	0.915	0.000	12 18 21
FTIM	0.016	-1.87	0.931	0.001	11 14 21 23
FTIM	0.001	-3.39	0.947	0.000	9 14 15 20 21
TAS	1.000	-3.67	0.958	0.042	14
TAS	1.000	-3.67	0.958	0.042	23
TAS	0.100	-3.67	0.958	0.004	6
TAS	0.500	-3.67	0.958	0.021	21
TAS	0.042	-3.67	0.958	0.002	10
TAS	0.067	-3.67	0.958	0.003	20
TAS	0.050	-3.67	0.958	0.002	12
TAS	0.050	-3.67	0.958	0.002	18
TAS	0.033	-3.67	0.958	0.001	11
TAS	1.000	-3.76	0.959	0.041	15
TAS	0.025	-3.76	0.959	0.001	13
TAS	0.033	-3.76	0.959	0.001	19
TAS	0.042	-3.76	0.959	0.002	9
TAS	0.025	-3.76	0.959	0.001	22
TAS	0.025	-3.76	0.959	0.001	7

POWER REDUCTION TABLE - RX #4

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
5	0.000
6	0.001
7	0.000
8	0.000
9	0.001
10	0.000
11	0.001
12	0.001
13	0.000
14	0.011
15	0.010
16	0.000
17	0.000
18	0.001
19	0.000
20	0.001
21	0.007
22	0.000
23	0.011

RECEIVER #5

Frequency: 4.167 MHz

Modulation Type: Secure Voice

Mean Ambient Noise: -125.74 dBm

Mean Receiver Noise: -126.00 dBm

D/U Threshold: 7.00

Mean Desired Signal: -107.04 dBm

Total Undesired Power: -122.03 dBm

SPS: 0.83

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.050	28.51	0.062	0.047	12 15
FTIM	0.002	5.98	0.738	0.001	10 12 14
FTIM	0.001	0.50	0.891	0.000	12 14 18 21 23
FTIM	0.016	-4.65	0.959	0.001	11 14 15 21
FTIM	0.002	-6.47	0.973	0.000	10 12 14 15
TAS	1.000	-5.91	0.977	0.023	14
TAS	1.000	-5.91	0.977	0.023	23
TAS	0.100	-5.91	0.977	0.002	6
TAS	0.500	-5.91	0.977	0.011	21
TAS	0.058	-5.91	0.977	0.001	5
TAS	0.025	-5.99	0.978	0.001	13
TAS	0.025	-5.99	0.978	0.001	22
FTIM	0.029	-7.16	0.978	0.001	5 14 15 21
TAS	0.042	-6.70	0.982	0.001	10
TAS	0.067	-6.70	0.982	0.001	20
TAS	0.050	-6.70	0.982	0.001	12
TAS	0.050	-6.70	0.982	0.001	18
TAS	0.033	-6.70	0.982	0.001	11
TAS	1.000	-6.78	0.983	0.017	15
TAS	0.033	-6.78	0.983	0.001	19

POWER REDUCTION TABLE - RX #5

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.000
6	0.000
7	0.000
8	0.000
9	0.000
10	0.000
11	0.000
12	0.002
13	0.000
14	0.006
15	0.006
16	0.000
17	0.000
18	0.000
19	0.000
20	0.000
21	0.003
22	0.000
23	0.006

RECEIVER #6

Frequency:	9.213 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-128.32 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-108.62 dBm
Total Undesired Power:	-123.19 dBm
SPS:	0.81

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.025	17.57	0.281	0.018	14 18 21 23
FTIM	0.042	17.90	0.318	0.029	10 15
FTIM	0.050	5.27	0.765	0.012	12 14 15
FTIM	0.013	2.15	0.857	0.002	13 21 23
FTIM	0.001	-2.07	0.931	0.000	10 15 20 21 23
FTIM	0.025	-2.86	0.941	0.001	14 15 22
FTIM	0.002	-3.45	0.951	0.000	10 12 14
TAS	1.000	-4.40	0.966	0.034	14
TAS	1.000	-4.40	0.966	0.034	23
TAS	0.500	-4.40	0.966	0.017	21
TAS	0.042	-4.40	0.966	0.001	10
TAS	0.058	-4.40	0.966	0.002	4
TAS	0.067	-4.40	0.966	0.002	20
TAS	0.050	-4.40	0.966	0.002	12
TAS	0.050	-4.40	0.966	0.002	18
TAS	0.033	-4.40	0.966	0.001	11
TAS	1.000	-4.48	0.966	0.034	15
TAS	0.025	-4.48	0.966	0.001	13
TAS	0.033	-4.48	0.966	0.001	19
TAS	0.042	-4.48	0.966	0.001	9

POWER REDUCTION TABLE - RX #6

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
7	0.001
8	0.000
9	0.000
10	0.004
11	0.000
12	0.003
13	0.002
14	0.015
15	0.018
16	0.000
17	0.000
18	0.002
19	0.000
20	0.001
21	0.001
22	0.001
23	0.011

RECEIVER #7

Frequency:	2.634 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-124.24 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-105.88 dBm
Total Undesired Power:	-121.23 dBm
SPS:	0.87

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.000	-1.14	0.918	0.000	4 11 12 23
FTIM	0.003	-1.59	0.926	0.000	6 14 18 21
FTIM	0.003	-1.92	0.929	0.000	6 20 21 23
FTIM	0.013	-4.63	0.959	0.001	14 21 22 23
FTIM	0.001	-5.20	0.966	0.000	9 10 14 15 21 23
FTIM	0.001	-5.37	0.967	0.000	4 12 14 21 23
FTIM	0.001	-7.34	0.980	0.000	14 15 20 21 22 23
TAS	1.000	-7.02	0.984	0.016	14
TAS	1.000	-7.02	0.984	0.016	23
TAS	0.500	-7.02	0.984	0.008	21
TAS	0.100	-7.02	0.984	0.002	6
TAS	0.058	-7.02	0.984	0.001	4
TAS	0.025	-7.11	0.984	0.000	13
TAS	0.025	-7.11	0.984	0.000	22
TAS	0.001	-8.90	0.985	0.000	9 10 14 15 21
TAS	0.042	-7.47	0.986	0.001	10
TAS	0.067	-7.47	0.986	0.001	20
TAS	0.050	-7.47	0.986	0.001	12
TAS	0.050	-7.47	0.986	0.001	18
TAS	0.033	-7.47	0.986	0.000	11

POWER REDUCTION TABLE - RX #7

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.001
5	0.000
6	0.001
8	0.000
9	0.000
10	0.000
11	0.000
12	0.001
13	0.000
14	0.005
15	0.004
16	0.000
17	0.000
18	0.000
19	0.000
20	0.001
21	0.004
22	0.001
23	0.006

RECEIVER #8

Frequency:	3.566 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-125.23 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-106.67 dBm
Total Undesired Power:	-121.77 dBm
SPS:	0.79

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.005	7.64	0.704	0.001	6 14 18 23
FTIM	0.003	4.74	0.781	0.001	6 15 18 21 23
FTIM	0.034	1.45	0.871	0.004	14 20 21 23
FTIM	0.001	1.47	0.873	0.000	10 14 20 21 23
FTIM	1.000	1.28	0.874	0.126	14 15 23
FTIM	0.016	-1.14	0.918	0.001	11 15 21 23
FTIM	0.003	-1.33	0.923	0.000	9 20 23
FTIM	0.025	-3.99	0.955	0.001	14 18 21 23
FTIM	0.003	-5.18	0.962	0.000	6 14 18 21
FTIM	0.001	-7.00	0.978	0.000	4 12 14 21 23
TAS	1.000	-6.26	0.980	0.020	14
TAS	1.000	-6.26	0.980	0.020	23
TAS	0.500	-6.26	0.980	0.010	21
TAS	0.100	-6.26	0.980	0.002	6
TAS	0.058	-6.26	0.980	0.001	4
TAS	0.025	-6.35	0.980	0.000	13
TAS	0.025	-6.35	0.980	0.000	22
TAS	0.042	-6.94	0.983	0.001	10
TAS	0.067	-6.94	0.983	0.001	20
TAS	0.050	-6.94	0.983	0.001	12

POWER REDUCTION TABLE - RX #8

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.001
7	0.000
9	0.000
10	0.000
11	0.000
12	0.000
13	0.000
14	0.069
15	0.042
16	0.000
17	0.000
18	0.002
19	0.000
20	0.004
21	0.006
22	0.000
23	0.068

RECEIVER #9

Frequency:	5.228 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-126.47 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-107.56 dBm
Total Undesired Power:	-122.39 dBm
SPS:	0.82

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.034	18.21	0.262	0.025	14 20 21
FTIM	0.001	1.09	0.880	0.000	10 14 20 21
FTIM	0.002	-0.77	0.914	0.000	8 20 23
FTIM	0.003	-1.09	0.918	0.000	12 15 18
FTIM	0.021	-4.69	0.958	0.001	10 14 21
TAS	0.042	-4.95	0.970	0.001	10
TAS	1.000	-5.41	0.974	0.026	14
TAS	1.000	-5.41	0.974	0.026	23
TAS	0.500	-5.41	0.974	0.013	21
TAS	0.100	-5.41	0.974	0.003	6
TAS	0.058	-5.41	0.974	0.002	4
TAS	0.025	-5.49	0.975	0.001	13
TAS	0.025	-5.49	0.975	0.001	22
TAS	0.067	-6.38	0.980	0.001	20
TAS	0.050	-6.38	0.980	0.001	12
TAS	0.050	-6.38	0.980	0.001	18
TAS	0.033	-6.38	0.980	0.001	11
FTIM	0.025	-7.30	0.981	0.000	18 21
TAS	1.000	-6.46	0.981	0.019	15
TAS	0.033	-6.46	0.981	0.001	19

POWER REDUCTION TABLE - RX #9

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.001
7	0.000
8	0.000
10	0.001
11	0.000
12	0.000
13	0.000
14	0.022
15	0.005
16	0.000
17	0.000
18	0.001
19	0.000
20	0.008
21	0.018
22	0.000
23	0.006

RECEIVER #10

Frequency:	5.086 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-126.38 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-107.50 dBm
Total Undesired Power:	-122.35 dBm
SPS:	0.79

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	Tx Numbers
FTIM	0.100	16.84	0.356	0.064	6 15
FTIM	0.050	4.17	0.809	0.010	12 14 15
FTIM	0.025	2.93	0.833	0.004	7 14 23
FTIM	0.001	0.38	0.893	0.000	14 20 21 22
FTIM	0.004	-2.29	0.934	0.000	3 15 21 23
FTIM	0.003	-3.13	0.944	0.000	6 15 20 21 23
FTIM	0.013	-3.19	0.944	0.001	14 15 21 22 23
FTIM	0.001	-3.19	0.947	0.000	14 15 20 21 22 23
FTIM	0.025	-6.50	0.973	0.001	14 15 18 21 23
FTIM	0.013	-6.11	0.974	0.000	8 14 21 23
TAS	1.000	-5.47	0.974	0.026	14
TAS	1.000	-5.47	0.974	0.026	23
TAS	0.500	-5.47	0.974	0.013	21
TAS	0.100	-5.47	0.974	0.003	6
TAS	0.058	-5.47	0.974	0.001	4
TAS	0.033	-5.54	0.975	0.001	11
TAS	0.025	-5.55	0.975	0.001	13
TAS	0.025	-5.55	0.975	0.001	22
TAS	0.042	-5.64	0.976	0.001	9
TAS	0.067	-6.41	0.981	0.001	20

POWER REDUCTION TABLE - RX #10

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.001
5	0.000
6	0.014
7	0.002
8	0.000
9	0.000
11	0.000
12	0.004
13	0.000
14	0.011
15	0.035
16	0.000
17	0.000
18	0.000
19	0.000
20	0.001
21	0.005
22	0.001
23	0.008

RECEIVER #11

Frequency:	4.925 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-126.28 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-107.43 dBm
Total Undesired Power:	-122.30 dBm
SPS:	0.86

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.001	-3.69	0.950	0.000	12 14 15 18 21 23
FTIM	0.029	-5.93	0.973	0.001	4 14 21 23
TAS	0.042	-5.49	0.975	0.001	10
TAS	1.000	-5.53	0.975	0.025	14
TAS	1.000	-5.53	0.975	0.025	23
TAS	0.500	-5.53	0.975	0.013	21
TAS	0.100	-5.53	0.975	0.003	6
TAS	0.058	-5.53	0.975	0.001	4
TAS	0.025	-5.62	0.975	0.001	13
TAS	0.025	-5.62	0.975	0.001	22
FTIM	0.002	-7.20	0.979	0.000	6 9 14 15 21
TAS	0.067	-6.45	0.981	0.001	20
TAS	0.050	-6.45	0.981	0.001	12
TAS	0.050	-6.45	0.981	0.001	18
TAS	0.042	-6.53	0.981	0.001	9
TAS	1.000	-6.54	0.981	0.019	15
TAS	0.033	-6.54	0.981	0.001	19
TAS	0.033	-6.54	0.981	0.001	5
TAS	0.025	-6.54	0.981	0.000	8
TAS	0.025	-6.54	0.981	0.000	7

POWER REDUCTION TABLE - RX #11

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.001
5	0.000
6	0.001
7	0.000
8	0.000
9	0.000
10	0.000
12	0.000
13	0.000
14	0.007
15	0.005
16	0.000
17	0.000
18	0.000
19	0.000
20	0.000
21	0.004
22	0.000
23	0.007

RECEIVER #12

Frequency:	6.228 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-127.04 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-107.92 dBm
Total Undesired Power:	-122.65 dBm
SPS:	0.85

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.033	26.03	0.098	0.030	5 15
FTIM	0.029	0.62	0.888	0.003	4 15 21 23
FTIM	0.001	-3.40	0.947	0.000	11 14 15 18 21 23
FTIM	0.016	-5.25	0.968	0.001	11 14 21
TAS	1.000	-5.06	0.971	0.029	14
TAS	1.000	-5.06	0.971	0.029	23
TAS	0.500	-5.06	0.971	0.014	21
TAS	0.100	-5.06	0.971	0.003	6
TAS	0.058	-5.06	0.971	0.002	4
TAS	0.025	-5.15	0.972	0.001	13
TAS	0.025	-5.15	0.972	0.001	22
TAS	0.067	-6.17	0.979	0.001	20
TAS	0.033	-6.17	0.979	0.001	11
TAS	0.050	-6.17	0.979	0.001	18
TAS	0.042	-6.17	0.979	0.001	10
TAS	1.000	-6.25	0.980	0.020	15
TAS	0.033	-6.25	0.980	0.001	19
TAS	0.042	-6.25	0.980	0.001	9
TAS	0.033	-6.25	0.980	0.001	5
TAS	0.025	-6.25	0.980	0.001	8

POWER REDUCTION TABLE - RX #12

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.002
5	0.001
6	0.001
7	0.000
8	0.000
9	0.000
10	0.000
11	0.001
13	0.000
14	0.008
15	0.006
16	0.000
17	0.000
18	0.000
19	0.000
20	0.000
21	0.005
22	0.000
23	0.008

RECEIVER #13

Frequency:	11.600 MHz
Modulation Type:	Unsecure Voice
Mean Ambient Noise:	-129.07 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	8.00
Mean Desired Signal:	-107.97 dBm
Total Undesired Power:	-123.48 dBm
SPS:	0.84

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.002	11.83	0.544	0.001	8 20
FTIM	0.005	3.54	0.816	0.001	6 18 23
FTIM	0.003	2.69	0.846	0.000	6 18 21
FTIM	0.003	1.70	0.868	0.000	6 14 18 21
TAS	1.000	-4.07	0.962	0.038	14
TAS	1.000	-4.07	0.962	0.038	23
TAS	0.050	-4.07	0.962	0.002	12
TAS	0.500	-4.07	0.962	0.019	21
TAS	0.100	-4.07	0.962	0.004	6
TAS	0.058	-4.07	0.962	0.002	4
TAS	0.067	-4.07	0.962	0.003	20
TAS	0.033	-4.07	0.962	0.001	11
TAS	0.050	-4.07	0.962	0.002	18
TAS	0.042	-4.07	0.962	0.002	10
TAS	1.000	-4.16	0.963	0.037	15
TAS	0.033	-4.16	0.963	0.001	19
TAS	0.042	-4.16	0.963	0.002	9
TAS	0.025	-4.16	0.963	0.001	22
TAS	0.033	-4.16	0.963	0.001	5
TAS	0.025	-4.16	0.963	0.001	8

POWER REDUCTION TABLE - RX #13

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.001
5	0.000
6	0.002
7	0.000
8	0.001
9	0.000
10	0.000
11	0.000
12	0.000
14	0.010
15	0.010
16	0.000
17	0.000
18	0.002
19	0.000
20	0.002
21	0.006
22	0.001
23	0.010

RECEIVER #14

Frequency:	19.604 MHz
Modulation Type:	Single Channel RATT
Mean Ambient Noise:	-130.78 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	11.00
Mean Desired Signal:	-105.68 dBm
Total Undesired Power:	-124.05 dBm
SPS:	0.86

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.001	-3.45	0.948	0.000	4 11 21
TAS	1.000	-4.55	0.967	0.033	23
TAS	0.050	-4.55	0.967	0.002	12
TAS	0.500	-4.55	0.967	0.017	21
TAS	0.100	-4.55	0.967	0.003	6
TAS	0.058	-4.55	0.967	0.002	4
TAS	0.067	-4.55	0.967	0.002	20
TAS	0.033	-4.55	0.967	0.001	11
TAS	0.050	-4.55	0.967	0.002	18
TAS	0.042	-4.55	0.967	0.001	10
TAS	1.000	-4.63	0.968	0.032	15
TAS	0.025	-4.63	0.968	0.001	13
TAS	0.033	-4.63	0.968	0.001	19
TAS	0.042	-4.63	0.968	0.001	9
TAS	0.025	-4.63	0.968	0.001	22
TAS	0.033	-4.63	0.968	0.001	5
TAS	0.025	-4.63	0.968	0.001	8
TAS	0.025	-4.63	0.968	0.001	7
TAS	0.008	-4.63	0.968	0.000	3
FTIM	0.001	-7.74	0.983	0.000	4 11 21 23

POWER REDUCTION TABLE - TX #14

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.001
5	0.000
6	0.001
7	0.000
8	0.000
9	0.000
10	0.000
11	0.001
12	0.000
13	0.000
15	0.008
16	0.000
17	0.000
18	0.000
19	0.000
20	0.001
21	0.004
22	0.000
23	0.008

RECEIVER #15

Frequency:	2.065 MHz
Modulation Type:	LINK-11
Mean Ambient Noise:	-123.45 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	27.00
Mean Desired Signal:	-85.22 dBm
Total Undesired Power:	-120.77 dBm
SPS:	0.87

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.034	5.51	0.758	0.008	20 21 23
FTIM	0.025	1.42	0.870	0.003	8 15 23
TAS	1.000	-7.66	0.987	0.013	14
TAS	1.000	-7.66	0.987	0.013	23
TAS	0.500	-7.66	0.987	0.007	21
TAS	0.100	-7.66	0.987	0.001	6
TAS	0.058	-7.66	0.987	0.001	4
TAS	0.025	-7.74	0.987	0.000	13
TAS	0.025	-7.74	0.987	0.000	22
TAS	0.050	-7.92	0.988	0.001	12
TAS	0.067	-7.92	0.988	0.001	20
TAS	0.033	-7.92	0.988	0.000	11
TAS	0.050	-7.92	0.988	0.001	18
TAS	0.042	-7.92	0.988	0.001	10
TAS	0.033	-8.00	0.988	0.000	19
TAS	0.042	-8.00	0.988	0.001	9
TAS	0.033	-8.00	0.988	0.000	5
TAS	0.025	-8.00	0.988	0.000	8
TAS	0.025	-8.00	0.988	0.000	7
TAS	0.008	-8.00	0.988	0.000	3

POWER REDUCTION TABLE - RX #15

TX	CHANGE IN SP
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.000
7	0.000
8	0.001
9	0.000
10	0.000
11	0.000
12	0.000
13	0.000
14	0.005
16	0.000
17	0.000
18	0.000
19	0.000
20	0.008
21	0.010
22	0.000
23	0.010

RECEIVER # 16

Frequency:	2.744 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-124.37 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-105.99 dBm
Total Undesired Power:	-121.31 dBm
SPS:	0.87

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.001	2.78	0.844	0.000	4 11 21 23
FTIM	0.004	-0.95	0.917	0.000	6 9
FTIM	0.016	-3.13	0.946	0.001	11 14 21 23
FTIM	0.001	-5.26	0.967	0.000	4 11 14 21 23
TAS	0.025	-6.66	0.982	0.000	7
TAS	1.000	-6.92	0.983	0.017	14
TAS	1.000	-6.92	0.983	0.017	23
TAS	0.500	-6.92	0.983	0.008	21
TAS	0.100	-6.92	0.983	0.002	6
TAS	0.058	-6.92	0.983	0.001	4
TAS	0.025	-7.00	0.984	0.000	13
TAS	0.025	-7.00	0.984	0.000	22
TAS	0.050	-7.39	0.986	0.001	12
TAS	0.067	-7.39	0.986	0.001	20
TAS	0.033	-7.39	0.986	0.000	11
TAS	0.050	-7.39	0.986	0.001	18
TAS	0.042	-7.39	0.986	0.001	10
TAS	1.000	-7.48	0.986	0.014	15
TAS	0.033	-7.48	0.986	0.000	19
TAS	0.042	-7.48	0.986	0.001	9

POWER REDUCTION TABLE RX #16

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.001
5	0.000
6	0.001
7	0.000
8	0.000
9	0.001
10	0.000
11	0.001
12	0.000
13	0.000
14	0.005
15	0.003
17	0.000
18	0.000
19	0.000
20	0.000
21	0.003
22	0.000
23	0.005

RECEIVER #17

Frequency:	2.410 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-123.95 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-105.65 dBm
Total Undesired Power:	-121.07 dBm
SPS:	0.81

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.042	29.63	0.050	0.040	9 14 23
FTIM	0.034	14.85	0.434	0.019	14 20 21 23
FTIM	0.001	7.85	0.695	0.000	13 14 18 21
FTIM	0.067	1.63	0.866	0.009	14 15 20
FTIM	0.033	-6.06	0.970	0.001	14 15 19 23
FTIM	0.001	-6.29	0.974	0.000	9 14 15 20 21
FTIM	0.001	-7.21	0.977	0.000	9 11 23
FTIM	0.050	-8.01	0.981	0.001	14 15 18
FTIM	0.021	-8.72	0.983	0.000	10 14 21 23
TAS	1.000	-7.25	0.985	0.015	14
TAS	1.000	-7.25	0.985	0.015	23
TAS	0.500	-7.25	0.985	0.008	21
TAS	0.100	-7.25	0.985	0.002	6
TAS	0.058	-7.25	0.985	0.001	4
TAS	0.025	-7.33	0.985	0.000	13
TAS	0.025	-7.33	0.985	0.000	22
TAS	0.050	-7.62	0.987	0.001	12
TAS	0.067	-7.62	0.987	0.001	20
TAS	0.033	-7.62	0.987	0.000	11
TAS	0.050	-7.62	0.987	0.001	18

POWER REDUCTION TABLE - RX #17

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.001
7	0.000
8	0.000
9	0.001
10	0.000
11	0.000
12	0.000
13	0.001
14	0.014
15	0.004
16	0.000
18	0.001
19	0.000
20	0.008
21	0.014
22	0.000
23	0.011

RECEIVER #18

Frequency:	7.795 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-127.78 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-108.34 dBm
Total Undesired Power:	-122.84 dBm
SPS:	0.80

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.050	17.30	0.291	0.035	6 14 21 23
FTIM	0.013	4.24	0.795	0.003	8 14 15 21
FTIM	0.013	-4.92	0.965	0.000	13 14 21
TAS	0.067	-4.65	0.968	0.002	20
TAS	1.000	-4.67	0.968	0.032	14
TAS	1.000	-4.67	0.968	0.032	23
TAS	0.500	-4.67	0.968	0.016	21
TAS	0.100	-4.67	0.968	0.003	6
TAS	0.058	-4.67	0.968	0.002	4
TAS	0.025	-4.75	0.969	0.001	13
TAS	0.025	-4.75	0.969	0.001	22
FTIM	0.013	-5.64	0.971	0.000	8 14 21 23
FTIM	0.001	-6.26	0.975	0.000	8 14 20 23
FTIM	0.021	-6.96	0.976	0.001	10 14 15 21 23
TAS	0.050	-5.94	0.978	0.001	12
TAS	0.033	-5.94	0.978	0.001	11
TAS	0.042	-5.94	0.978	0.001	10
TAS	1.000	-6.02	0.978	0.022	15
TAS	0.033	-6.02	0.978	0.001	19
TAS	0.042	-6.02	0.978	0.001	9

POWER REDUCTION TABLE - RX #18

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.010
7	0.000
8	0.002
9	0.000
10	0.000
11	0.000
12	0.000
13	0.001
14	0.029
15	0.006
16	0.000
17	0.000
19	0.000
20	0.001
21	0.015
22	0.001
23	0.018

RECEIVER #19

Frequency:	4.529 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-126.01 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-107.24 dBm
Total Undesired Power:	-122.16 dBm
SPS:	0.86

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.001	6.71	0.734	0.000	9 11 14
FTIM	0.003	-6.48	0.973	0.000	6 20 21
TAS	1.000	-5.71	0.976	0.024	14
TAS	1.000	-5.71	0.976	0.024	23
TAS	0.500	-5.71	0.976	0.012	21
TAS	0.100	-5.71	0.976	0.002	6
TAS	0.058	-5.71	0.976	0.001	4
TAS	0.025	-5.80	0.977	0.001	13
TAS	0.025	-5.80	0.977	0.001	22
TAS	0.050	-6.57	0.981	0.001	12
TAS	0.050	-6.57	0.981	0.001	18
TAS	0.067	-6.57	0.981	0.001	20
TAS	0.033	-6.57	0.981	0.001	11
TAS	0.042	-6.57	0.981	0.001	10
TAS	1.000	-6.66	0.982	0.018	15
TAS	0.042	-6.66	0.982	0.001	9
TAS	0.017	-6.66	0.982	0.000	16
TAS	0.033	-6.66	0.982	0.001	5
TAS	0.025	-6.66	0.982	0.000	8
TAS	0.025	-6.666	0.982	0.000	7

POWER REDUCTION TABLE - RX #19

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.001
7	0.000
8	0.000
9	0.001
10	0.000
11	0.001
12	0.000
13	0.000
14	0.007
15	0.005
16	0.000
17	0.000
18	0.000
20	0.001
21	0.003
22	0.000
23	0.007

RECEIVER #20

Frequency:	8.027 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-127.87 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-108.40 dBm
Total Undesired Power:	-123.01 dBm
SPS:	0.84

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.021	21.42	0.206	0.017	10 21
FTIM	0.021	14.71	0.395	0.013	9 14 21
FTIM	0.001	2.32	0.854	0.000	4 13 14 15 21
FTIM	0.021	2.29	0.855	0.003	10 15 21 23
TAS	1.000	-4.61	0.967	0.033	14
TAS	1.000	-4.61	0.967	0.033	23
TAS	0.500	-4.61	0.967	0.016	21
TAS	0.100	-4.61	0.967	0.003	6
TAS	0.058	-4.61	0.967	0.002	4
TAS	0.025	-4.69	0.968	0.001	13
TAS	0.025	-4.69	0.968	0.001	22
TAS	0.050	-4.73	0.969	0.002	18
FTIM	0.050	-5.53	0.970	0.002	14 18
TAS	0.050	-5.90	0.977	0.001	12
TAS	0.033	-5.90	0.977	0.001	11
TAS	0.042	-5.90	0.977	0.001	10
TAS	1.000	-5.99	0.978	0.022	15
TAS	0.042	-5.99	0.978	0.001	9
TAS	0.017	-5.99	0.978	0.000	16
TAS	0.033	-5.99	0.978	0.001	5

POWER REDUCTION TABLE - RX #20

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.001
5	0.000
6	0.001
7	0.000
8	0.000
9	0.002
10	0.002
11	0.000
12	0.000
13	0.001
14	0.013
15	0.005
16	0.000
17	0.000
18	0.001
19	0.000
21	0.010
22	0.000
23	0.008

RECEIVER #21

Frequency:	18.205 MHz
Modulation Type:	Single Channel RATT
Mean Ambient Noise:	-130.54 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	11.00
Mean Desired Signal:	-105.56 dBm
Total Undesired Power:	-123.97 dBm
SPS:	0.85

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.002	-2.79	0.940	0.000	4 11 14
TAS	1.000	-3.87	0.960	0.040	14
TAS	1.000	-3.87	0.960	0.040	23
TAS	0.050	-3.87	0.960	0.002	12
TAS	0.100	-3.87	0.960	0.004	6
TAS	0.050	-3.87	0.960	0.002	18
TAS	0.058	-3.87	0.960	0.002	4
TAS	0.067	-3.87	0.960	0.003	20
TAS	0.033	-3.87	0.960	0.001	11
TAS	0.042	-3.87	0.960	0.002	10
TAS	1.000	-3.96	0.961	0.039	15
TAS	0.025	-3.96	0.961	0.001	13
TAS	0.042	-3.96	0.961	0.002	9
TAS	0.025	-3.96	0.961	0.001	22
TAS	0.017	-3.96	0.961	0.001	16
TAS	0.033	-3.96	0.961	0.001	5
TAS	0.025	-3.96	0.961	0.001	8
TAS	0.025	-3.96	0.961	0.001	7
TAS	0.033	-3.96	0.961	0.001	19
TAS	0.008	-3.96	0.961	0.000	3

POWER REDUCTION TABLE - RX #21

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.001
5	0.000
6	0.001
7	0.000
8	0.000
9	0.000
10	0.000
11	0.001
12	0.000
13	0.000
14	0.010
15	0.009
16	0.000
17	0.000
18	0.000
19	0.000
20	0.001
22	0.000
23	0.010

RECEIVER #22

Frequency:	12.465 MHz
Modulation Type:	Secure Voice
Mean Ambient Noise:	-129.30 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	7.00
Mean Desired Signal:	-109.07 dBm
Total Undesired Power:	-123.56 dBm
SPS:	0.82

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.025	11.54	0.559	0.011	8 14
FTIM	0.021	1.44	0.874	0.003	10 14 21
FTIM	0.021	1.30	0.876	0.003	10 14 15 21 23
FTIM	0.100	0.57	0.890	0.011	6 14 15
FTIM	0.007	0.09	0.898	0.001	6 15 20
SE	0.050	-3.68	0.949	0.003	12
FTIM	0.002	-4.89	0.961	0.000	13 14 20
TAS	1.000	-3.98	0.961	0.039	14
TAS	1.000	-3.98	0.961	0.039	23
TAS	0.050	-3.98	0.961	0.002	12
TAS	0.500	-3.98	0.961	0.019	21
TAS	0.100	-3.98	0.961	0.004	6
TAS	0.050	-3.98	0.961	0.002	18
TAS	0.058	-3.98	0.961	0.002	4
TAS	0.067	-3.98	0.961	0.003	20
TAS	0.033	-3.98	0.961	0.001	11
TAS	0.042	-3.98	0.961	0.002	10
TAS	1.000	-4.06	0.962	0.038	15
TAS	0.025	-4.06	0.962	0.001	13
TAS	0.042	-4.06	0.962	0.002	9

POWER REDUCTION TABLE - RX #22

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.006
7	0.000
8	0.005
9	0.000
10	0.001
11	0.000
12	0.001
13	0.001
14	0.017
15	0.014
16	0.000
17	0.000
18	0.000
19	0.000
20	0.001
21	0.007
23	0.010

RECEIVER #23

Frequency:	22.419 MHz
Modulation Type:	Multi-channel RATT
Mean Ambient Noise:	-131.22 dBm
Mean Receiver Noise:	-126.00 dBm
D/U Threshold:	12.00
Mean Desired Signal:	-104.82 dBm
Total Undesired Power:	-124.17 dBm
SPS:	0.86

Most Severe Interactions

Type	Duty Cycle	EIL (dB)	IPS	IEP	TX Numbers
FTIM	0.034	4.75	0.783	0.007	15 20 21
FTIM	0.001	1.73	0.865	0.000	8 14 20 21
TAS	1.000	-4.97	0.971	0.029	14
TAS	0.050	-4.97	0.971	0.001	12
TAS	0.500	-4.97	0.971	0.015	21
TAS	0.100	-4.97	0.971	0.003	6
TAS	0.050	-4.97	0.971	0.001	18
TAS	0.058	-4.97	0.971	0.002	4
TAS	0.067	-4.97	0.971	0.002	20
TAS	0.033	-4.97	0.971	0.001	11
TAS	0.042	-4.97	0.971	0.001	10
TAS	1.000	-5.05	0.971	0.029	15
TAS	0.025	-5.05	0.971	0.001	13
TAS	0.025	-5.05	0.971	0.001	22
TAS	0.042	-5.05	0.971	0.001	9
TAS	0.017	-5.05	0.971	0.000	16
TAS	0.033	-5.05	0.971	0.001	5
TAS	0.025	-5.05	0.971	0.001	8
TAS	0.025	-5.05	0.971	0.001	7
TAS	0.033	-5.05	0.971	0.001	19

POWER REDUCTION TABLE - RX #23

TX	CHANGE IN SPS
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.001
7	0.000
8	0.000
9	0.000
10	0.000
11	0.000
12	0.000
13	0.000
14	0.007
15	0.010
16	0.000
17	0.000
18	0.000
19	0.000
20	0.006
21	0.009
22	0.000

LIST OF REFERENCES

1. R.M. Bauman, C.E. Hobbis, R.K. Royce, Analysis of the HF Architecture of the Integrated Communication System - Stage 3 (ICS-3), NRL Report 8269, Naval Research Laboratory, Washington, D.C., May 1979.

2. S.T. Li, EMC Analysis of HF Wideband Communication Systems, NOSC Technical Note 1365, Naval Ocean Systems Center, San Diego, CA, September 1984.

3. J.W. Rockway, J.C. Logan, S.T. Li, Extension of Shipboard Exterior Communication Design Analysis to Wideband Systems, IEEE 1985 International Communication Conference, Chicago, IL, June 1985.

4. LHD-1 RF Communication System Study, Naval Ocean Systems Center, San Diego, CA, April 1984.

5. B.E. Kaiser, Principles of Electromagnetic Compatibiltiy, ARTECH House, INC., 1979.

6. R. Gagliardi, Introduction to Communications Engineering, John Wiley & Sons, 1978.

7. K. Clubb, D. Wheeler, E. Pappas, The COSAM II (DECAL/PECAL) Wideband and Narrowband RF Architecture Analysis Program User's Manual, ECAC-CR-86-112, Electromagnetic Compatibility Analysis Center, Annapolis, MD, February 1987.

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